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Level of knowledge, competence and interest of agronomists in digitalisation of agriculture in Croatia

Razina znanja, kompetencije i zainteresiranost agronoma za digitalizaciju poljoprivrede u Hrvatskoj

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ABSTRACT

The aim of this paper was to investigate the current level of knowledge, competence and interest of agronomists in participating in the digitalisation of agriculture in Croatia, as well as the role of some stakeholders in training the farmers since it can be assumed that agronomists will play a significant, perhaps even decisive role in the process of digitalisation of agriculture in Croatia. Primary data were collected through a survey using an online questionnaire (n = 80) as a research tool. The target group of respondents were agronomists, regardless of their age and occupation. According to the research findings, 20.0% of respondents have some difficulties in using digital technologies, while 12.5% of respondents do not use digital technologies at all. On the 5-point agreement scale (1 to 5), respondents rated the importance of agronomists in the digitalisation of agriculture at 4.54, their personal interest in participating in digitalisation at 4.38, and their current competence for digitalisation at 3.09. The main conclusions are that the majority of respondents believe that: 1. Agronomists are important and well-trained to participate in the digitalisation process of Croatian agriculture.; 2. Faculties, extension services, the Chamber of Croatian Agronomists, distributors and producers of software and digital equipment should play a key role in providing additional training in digital skills.; 3. Knowledge of digital technologies is equally important for medium and large farms as well as for state units.

Keywords: education, extension services, rural area, skill sources, knowledge sources

SAŽETAK

Cilj rada bio je istražiti trenutnu razinu znanja, kompetencije i zainteresiranosti agronoma za sudjelovanje u digitalizaciji hrvatske poljoprivrede kao i ulogu pojedinih subjekata u osposobljavanju budućih poljoprivrednika, budući da možemo pretpostaviti da će agronomi imati značajnu, možda čak i odlučujuću ulogu u procesu digitalizacije poljoprivrede u Hrvatskoj. Primarni podaci prikupljeni su putem metode ankete, a kao instrument istraživanja je korišten online anketni upitnik (n = 80). Ciljana skupina ispitanika bili su agronomi, bez obzira na dob i zanimanje. Prema podatcima istraživanja, 20,0 % ispitanika ima određene poteškoće u korištenju digitalnih tehnologija, dok 12,5 % ispitanika uopće ne koristi digitalne tehnologije. Na ljestvici slaganja od pet stupnjeva(od 1 do 5) ispitanici su važnost agronoma u digitalizaciji poljoprivrede ocijenili ocjenom 4,54, osobni interes za sudjelovanje u digitalizaciji 4,38, a njihovu trenutnu kompetenciju za digitalizaciju 3,09. Glavni zaključci proizašli iz istraživanja su: 1. agronomi su važni i dobro obučeni za sudjelovanje u procesu digitalizacije hrvatske poljoprivrede; 2. fakulteti, savjetodavne službe, Hrvatska agronomska komora, distributeri i proizvođači softvera i digitalne opreme trebaju imati ključnu ulogu u pružanju dodatnog osposobljavanja vezanog za digitalne vještine; 3. poznavanje digitalnih tehnologija jednako je važno za srednja i velika gospodarstva kao i za državne jedinice.

Ključne riječi: obrazovanje, savjetodavne usluge, ruralno područje, izvori vještina, izvori znanja

INTRODUCTION

Increasing concerns about global food security have accelerated the need for next-generation industrial farms and intensive production methods in agriculture (Abbasi et al., 2022). Disruptive technologies are at the heart of the fourth industrial revolution such as the Internet of Things (IoT), Data Science, Deep Learning and areas such as agriculture, plant science, animal science, food science and social science (Catal et al., 2019; Sott et al., 2020; Zhai et al., 2020; Liu et al., 2021; Javaid et al., 2022). According to Aubert et al. (2012), Wolfert et al. (2017), Ingram and Maye (2020), Khanna et al. (2022) and Cui and Wang (2023), digital agriculture leads to incremental improvements in efficiency, productivity and sustainability at the farm level and across the value chain. Sensor systems and related analytics provide producers with better information to make timely decisions with more predictable outcomes, while automation of tasks through sensor technologies and machine learning can increase reliability (Ingram and Maye, 2020). According to the authors, rapid developments in the Internet of Things (IoT), cloud computing, robotics and artificial intelligence are accelerating the transition to smart agriculture and the advancement of Big Data and precision agriculture to improve agricultural sustainability. However, while all these new technologies associated with digital agriculture promise multiple benefits, they also bring with them technical, social, economic, ethical and practical issues that have significant implications for how commercial agriculture is structured, practised and managed (Ingram and Maye, 2020). Despite the multiple benefits of digital agriculture, the adoption rate in Europe is still low and depends on a variety of variables, such as the size of agricultural producers, location, organisational and institutional factors (Ali and Kumar, 2011; Ritaban et al., 2014; Paustian and Theuvsen, 2017; Kumar et al., 2021; Scuderi et al., 2022). In Croatia, for example, awareness of the potential of digital agriculture tools is gradually increasing among farmers (Lončaić et al., 2023). The application of digital technologies in agricultural production is a great challenge, but at the same time an inevitable change for all stakeholders in the agriculture and food production sector. A prerequisite for successful digitalisation is the training and competence of all stakeholders, from local and regional authorities, through farmers and agronomists to traders, sellers and even consumers. But it seems that the greatest challenge will be to achieve sufficient infrastructural and financial capacities to transfer knowledge, skills and competencies to the rural actors and farmers, especially small and medium-sized farmers. There is a strong digital divide between countries, caused by differences in access to information and technology, but also within countries themselves, between rural and urban areas as well as different production sectors (Scuderi et al., 2022). Digital agriculture systems are much more developed in urban areas than in rural areas (Spielman, 2006; Gumbi et al., 2023). Given that we can expect a significant, perhaps crucial, role of agronomists in this process, this paper aimed to investigate the current level of knowledge, competence and interest of agronomists participating in the digitalisation of agriculture in Croatia, as well as the role of some stakeholders in the education of farmers. In the continuation of the paper, the materials and methods section describes the survey instrument, the survey procedure and the statistical analysis of the data obtained. In the Results and Discussion sections, the results are presented and discussed with regard to the importance, the current level of competence and knowledge of agronomists for participation in the digitalisation of Croatian agriculture and the importance of the individual actors for the further training of agronomists in Croatia, from which conclusions are drawn in the last section.

MATERIALS AND METHODS

The primary data was collected using the survey method, whereby an online questionnaire (n = 80) was used as a research instrument. The survey was conducted using online software as it has advantages over face-to-face, telephone or postal data collection, such as covering a wider geographical area, quick response time, lower costs and fewer errors (Dillman et al., 2014; Bonnichsen and Olsen, 2016; Khachatryan et al., 2021; Mariel et al., 2021). However, there are also some shortages of using

online surveys, including the availability of computers and Internet access, sampling and representativeness issues, and non-response bias (Bonnichsen and Olsen, 2016; Mariel et al., 2021). Given the difficulty in obtaining a random sample that faithfully represents the population, a random non-probabilistic sample was reached. The survey was disseminated from October to December 2022 through various channels, starting with emails to the main agricultural companies, family farms, regional and local units and through social networks. In accordance with the law on the protection of personal data and the guarantee of digital rights, all participants were informed before the start of the survey about the study procedure and data management, as well as that their participation is voluntary and that they therefore have the right to withdraw from the study at any time and without giving any reason. The target group of respondents were agronomists (agricultural experts with a degree in the scientific field of biotechnical sciences, the field of agriculture – agronomy), regardless of their legal form and scope of production. Before taking part in the survey, the participants were asked about completed agricultural training for agronomists. Only participants who have completed an education in the scientific field of biotechnical sciences, the field of agriculture – agronomy could take part in the survey. The full questionnaire contained a total of 35 open and closed questions, divided into several groups. For this study, only 8 socio-demographic questions (age, place of residence, years of completion of highest level of education, experience in agriculture, labour situation, employment by sector and employment in agriculture) and 11 questions on familiarity with the concept of digital agriculture and terms related to digital agriculture, from which sources they were educated about digital agriculture, whether they have difficulties with the use of ICT on the farm, whether they consider the digitalisation of Croatian agriculture necessary or useful, to express their opinion on digital technologies from the perspective of business management, to express their opinion on the importance of agronomists and advisory services in the digitalisation of agriculture, personal interest and current competence for digitalisation and future training of agronomists. The statements regarding the current competence, knowledge and additional training of agronomists for the digitalisation of Croatian agriculture, their importance for the digitalisation of agriculture and the importance of individual actors in the education and training of agronomists were measured using a 5-point agreement scale.

Statistical analysis was carried out using the statistical software package IBM SPSS Statistics V26. Descriptive statistics were used to describe the sample (percentages, frequencies, arithmetic mean and standard deviation). The collected data were analysed using descriptive statistics (frequency analysis, arithmetic mean, mode, median and standard deviation) and parametric tests (independent samples t-test, one-way test ANOVA). Descriptive statistical analysis was used to describe the socio-demographic characteristics of the sample and the knowledge about digital agriculture. The independent samples t-test and ANOVA were conducted to determine the significant differences between the segments in terms of respondents' socio-demographic characteristics and agronomists' knowledge about digital agriculture. The results were illustrated in suggestive graphics and tables and have been interpreted accordingly.

RESULTS AND DISCUSSION

The respondents included 40.0% females and 60.0% males, with 48.8% residing in urban areas, 38.7% in rural areas, and 12.5% in suburban settlements. In terms of age, 33.8% were between 23 and 34 years old, 28.7% were between 35 and 44, 25.0% were between 45 and 54, and 12.5% were older than 54. The respondents' experience in agriculture varied, with equal proportions (45.0%) having up to 10 years and more than 10 years of experience, while 10.0% were not involved in agriculture. Additionally, 16.3% of the surveyed agronomists own their own company, trade, or family farm, and 81.3% are currently employed in agriculture, either full or part-time. The majority of respondents (58.8%) are employed in the primary sector, including agriculture, fishing, and forestry, while 27.4% are in the quaternary sector

(administration, knowledge, education, health care) (Table 1). Most respondents came from Osijek-Baranja County (55.0%), the city of Zagreb (14.0%) and Vukovar-Srijem County (13.0%). According to the Croatian Bureau of Statistics and the Croatian Employment Service (Croatian Bureau of Statistics, 2022; Employment Service, 2022), 3,181 people completed agricultural training in Croatia in 2022 and 603 people were employed in the primary sector (agriculture, fishing, forestry) in Croatia, of which 166 people came from Osijek-Baranja County, 69 from Vukovar-Srijem County and 42 from the city of Zagreb. 92.0% of the surveyed agronomists are familiar with the concept of digital agriculture, 20.0% have some difficulties with the use of digital technologies, while 12.5% of the respondents do not use digital technologies at all. The majority (55.0%) of the surveyed agronomists consider the digitalisation of Croatian agriculture useful and necessary and believe that agronomists are the key factor in the digitalisation process of Croatian agriculture.

Most of the agronomists surveyed found out about digital agriculture through independent research on the Internet (28.7%), 25.0% through the media (news, portals, newspaper articles, etc.) and 21.3% of respondents through scientific articles. When asked which terms they were familiar with, the agronomists stated that they were primarily familiar with the terms: digital agriculture (83.3%), precision agriculture (80.0%) and smart agriculture (66.3%). Of the other terms, they are familiar with artificial intelligence (46.3%), e-agriculture (36.3%) and cloud ICT systems (26.3%), and least familiar with the term Agriculture 4.0 (12.5%) (Figure 1). According to a study conducted in Italy by Scuderi et al. (2022), the market growth potential of Agriculture 4.0 and Farming 4.0 solutions is very high, but the adaptation of the aforementioned technological innovation is still low. As in Croatia, Italian companies are increasingly aware of the opportunities offered by Agriculture 4.0, but there are still enormous technological limits that must be resolved for full application.

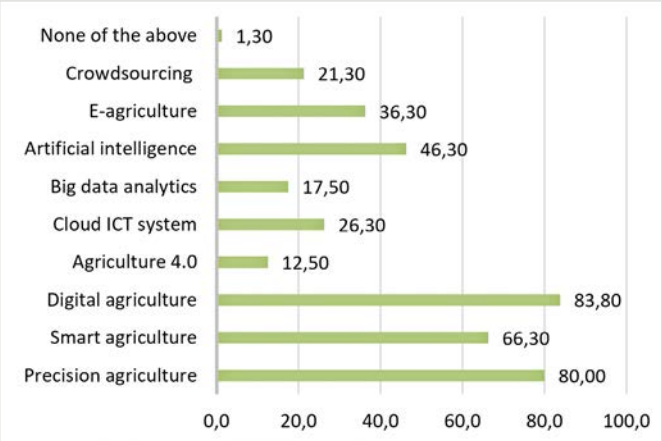

Figure 1. Well-known terms

The agronomists surveyed were also asked to express their opinions on digital technologies from the perspective of company management, regardless of whether they are employed by a company or own their own business. The results are shown in Figure 2. Agronomists overwhelmingly believe that digital agriculture helps to simplify daily work and administration (73.8%), reduce costs and increase turnover (57.5%), is necessary for the management and development of the company (47.5%) as well as for the competitiveness of production on the market (45.0%), while only 10.0% of them believe that digital agriculture has no impact on companies. In the administrative sector, digitalisation is perceived as making work easier, as information is more accessible (Scheepers et al., 2022). Recent studies have shown that digital agriculture has led to a 13.0% reduction in costs per hectare and a 30.0% reduction in the use of water, fuel, fertilizers and pesticides, in terms of environmental sustainability, and that the carbon footprint of crops has been reduced by 15.0% (Scuderi et al., 2022; Liao and Zhou, 2023; Zhu et al., 2023). Studies have also shown that the adaptation of digital agriculture depends on the size of the company and production and that digital solutions in agriculture are mainly focused on precision agriculture and the so-called Internet of Things (IoT) (Jin et al., 2020; Vecchio et al., 2020; Zhang et al., 2023).

Table 1. Overview of respondents' sociodemographic characteristics

		Frequency	Percent (%)
Gender	Male	48	60.0
	Female	32	40.0
Age	23 - 34	27	33.8
	35 - 44	23	28.7
	45 -54	20	25.0
	> 54	10	12.5
Place of residence	Urban	39	48.8
	Suburban	10	12.5
	Rural	31	38.7
Years of completion of the highest level of education	<10 yrs	40	50.0
	10 - 20	25	31.2
	> 20 yrs	15	18.8
Experience in agriculture	up to 10 yrs	36	45.0
	10 - 20 yrs	14	17.5
	> 20 yrs	22	27.5
	I am not employed in agriculture	8	10.0
Labour situation	Own company, trade, family farm	13	16.3
	Employed	62	77.5
	Employed part-time	3	3.8
	Retired	2	2.4
Employment by sector	Primary (agriculture, fishing, forestry)	47	58.8
	Secondary (industry, mining, construction)	2	2.5
	Tertiary (non-productive economic activities)	9	11.3
	Quaternary (administration, knowledge, education, healthcare)	21	27.4
Currently employed in the agriculture profession	Yes	65	81.3
	No	15	18.7

Undoubtedly, digital technologies in agriculture enable a better understanding of the interdependence of factors that determine different aspects of the business, as the collection of data, analysis and results can be carried out with a single system and are less subject to errors (Akkem et al., 2023; Niedbała et al., 2023).

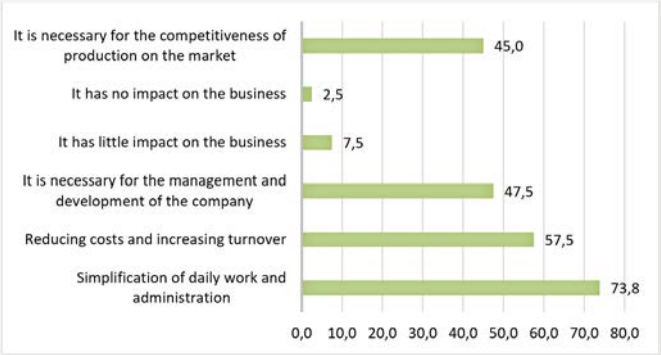

Figure 2. A statement on digital technologies from the perspective of the management and development of the company in which the respondents are employed

On a 5-point agreement scale (1 - not important, 5 - very important), respondents rated the importance of agronomists for the digitalisation of agriculture at 4.54, personal interest in participating in digitalisation at 4.38, but current competence for digitalisation at only 3.09. They also rated the importance of establishing an advisory service for the digitalisation of agriculture led by agronomists as high (4.50). To check whether there are differences between the individual answers with regard to the current competence of agronomists for digitalisation and the importance of each actor in the continuing education of agronomists, an independent t-test was carried out. The differences in the arithmetic mean of the ratings given by the agronomists on the importance of agronomists in the digitalisation of agriculture, on the importance of individual actors in the training of agronomists and on the importance of knowledge of digital technologies in agriculture were tested in terms of the age of the respondents, the year of completion of their final level of education and familiarity with the concept of digital agriculture. Respondents were asked to give their opinions on the variables presented in the tables below. The results of the independent samples t-test showed that there is a statistically significant difference in the statement of current competence of agronomists for the digitalisation of agriculture ($t = 3.223$, $df = 78$, $P < 0.01$) with respect to the gender of the respondents (Table 2). Table 2 shows that females (M = 3.38, 1.003) compared to male agronomists (M = 2.66, 0.937) are, according to their own opinion, more competent in the digitalisation of Croatian agriculture.

Moreover, the competence of agronomists to digitalise agriculture is statistically significant ($t = 2.068$, $df = 78$, $P < 0.05$) in relation to the employment of agronomists in their own profession (Table 3). Agronomists who are employed in their profession (M = 3.20, 0.971) are more competent in the digitalisation of Croatian agriculture than those who are not employed in their profession (M = 2.60, SD = 1.183).

It is also evident from Table 4 that there are statistically significant differences between the variables regarding the competence of agronomists for the digitalisation of agriculture ($t = 2.793$, $df = 78$, $P < 0.01$) in terms of respondents' familiarity with the concept of digital agriculture. Agronomists who are familiar with the concept of digital agriculture (M = 3.18, SD = 0.984) are also those who are more competent in digitalising agriculture.

A statistically significant difference was found between the statement of the importance of agronomists for the digitalisation of agriculture and the variable regarding the year of completion of their final level of education ($F = 3.451$, $df = 2$, $P < 0.05$). Agronomists who completed their education in the last ten years (M = 4.72, SD = 0.554) and between ten and twenty years ago (M = 4.48, SD = 0.770) are more likely to agree with the statement that agronomists are important for the digitalisation of agriculture than those who completed their education more than twenty years ago (Table 5). Agronomists who graduated before the digital boom in agriculture did not have the opportunity to be exposed to these technologies during their education, as deep learning applications and the Internet of Things (IoT) were introduced in agriculture after 2010, while most higher education institutions today recognize the importance

of preparing future-ready agronomists for the challenges of digitalisation (Soma and Nuckchady, 2021; Charatsari et al., 2023). According to Table 6, there are statistically significant differences between the variables stating that faculties are important actors in the continuing education of agronomists (t = 2.117, df = 78, $P < 0.05$), as well as the Croatian Chamber of Agronomists (t = 2.410, df = 78, $P < 0.05$) in terms of respondents' familiarity with the concept of digital agriculture. Agronomists who are familiar with the concept of digital agriculture believe that faculties (M = 3.96, SD = 1.053) and the Croatian Chamber of Agronomists (M = 3.97, SD =1.085) are important actors in the continuing education of agronomists.

Table 2. T-test results comparing the current competence of agronomists for the digitalisation of agriculture in relation to the gender of the respondents

Agronomists are educated to participate in the digitalisation process of Croatian agriculture	Gender				t-test	*P*
	Female		Male			
	M	SD	M	SD		
	3.38	1.003	2.66	0.937	3.223	0.002**

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

Table 3. T-test results comparing the current competence of agronomists for the digitalisation of agriculture with regard to their employment in the profession

Agronomists are educated to participate in the digitalisation process of Croatian agriculture	Employment in the profession				t-test	*P*
	Yes		No			
	M	SD	M	SD		
	3.20	0.971	2.60	1.183	2.068	0.042*

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

Table 4. T-test results comparing the current competence of agronomists for the digitalisation of agriculture in terms of familiarity with the concept of digital agriculture

Agronomists are educated to participate in the digitalisation process of Croatian agriculture	Familiarity with the concept of digital agriculture				t-test	*P*
	Yes		No			
	M	SD	M	SD		
	3.18	0.984	2.00	1.095	2.793	0.007**

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

Table 5. Analysis of variance for the variable regarding the importance of agronomists for the digitalisation of agriculture according to the year of completion of agronomists' final level of education

Importance of agronomists for the digitalisation of agriculture	Familiarity with the concept of digital agriculture						F	*P*
	<10		10-20		>20			
	M	SD	M	SD	M	SD		
	4.72	0.554	4.48	0.770	4.13	1.125	3.451	0.037*

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

Table 6. T-test results comparing the importance of the individual actors in the continuing education of agronomists in relation to familiarity with the concept of digital agriculture

The importance of individual actors in the continuing education of agronomists	Familiarity with the concept of digital agriculture				t-test	*P*
	Yes		No			
	M	SD	M	SD		
Faculties	3.96	1.053	3.00	1.265	2.117	0.037*
Advisory Service	3.59	1.238	3.67	0.816	-0.140	0.889
Croatian Chamber of Agronomists	3.97	1.085	2.83	1.472	2.410	0.018*
Employers	3.91	1.088	3.50	1.378	0.862	0.392
Distributors and manufacturers of software and equipment	3.88	1.097	3.33	0.816	1.187	0.239
Companies and organisations	3.93	1.102	3.50	0.837	0.937	0.352

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

The results of the study conducted are consistent with the study by Hansen et al. (2022) in their review of digital adaptation in Australian agriculture. The authors concluded that Australian agriculture relies heavily on knowledge transfer from agronomists, as they invest time in understanding how the technology works and are seen as trusted key players in educating the wider farming community about digital agriculture. But overall, the authors argue, practice will only change if researchers, technology developers, suppliers, farmers and advisors work together across the digital innovation system (Fielke et al., 2020; Hansen et al., 2022).

Table 7 shows the results of the analysis of variance (ANOVA), which revealed statistically significant differences between the variables Croatian Chamber of Agronomists ($F = 3.380$, df = 3, $P < 0.05$), traders and producers of software and equipment for digital agriculture ($F = 4.135$, df = 3, $P < 0.01$) and companies and organisations for the dissemination and transfer of knowledge and skills in the field of digitalisation of agriculture important for the training of agronomists ($F = 6.050$, df = 3, $P < 0.01$), and the age of respondents. These findings are consistent with Ingram and Maye's (2020) research on the digital transformation of agriculture.

Table 7. Analysis of variance for the variable importance of the individual actors in the continuing education of agronomists according to the age of the respondents

The importance of individual actors in the continuing education of agronomists	Age								*F*	*P*
	23-34		35-44		45-54		>54			
	M	SD	M	SD	M	SD	M	SD		
Faculties	3.93	1.107	4.09	1.041	3.60	0.995	3.90	1.370	0.723	0.541
Advisory Service	3.74	1.259	3.78	1.278	3.15	0.745	3.70	1.567	1.258	0.295
Croatian Chamber of Agronomists	3.70	1.103	4.35	0.885	3.40	1.314	4.30	1.059	3.380	0.023*
Employers	4.00	1.074	4.13	0.920	3.55	1.146	3.60	1.430	1.320	0.274
Distributors and manufacturers of software and equipment	4.00	1.0774	4.17	1.072	.315	1.040	4.00	0.667	4.135	0.009**
Companies and organisations	4.04	1.018	4.30	1.063	3.10	1.021	4.20	0.632	6.050	0.001**

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

The authors agree that the knowledge capacities of all actors in the agricultural knowledge and innovation system are important. Improving skills at every level, from farmers and extension workers to new technology and software providers and established researchers, is important if digital technologies are to deliver their full value, according to the authors. Co-learning and collaboration in implementing new technologies should be an important aspect of future development and research (2020).

Hansen et al. (2020) conducted a survey of 739 Norwegian farmers and concluded that training in agricultural knowledge and innovation, a better management system that avoids data overload, and access to extension services and colleagues are important for farmers' well-being and that providers and extension services need to offer adequate training in agricultural knowledge and innovation system. Future extension service models could provide back-office services that monitor key performance variables and help farmers interpret the data in order to make better decisions. Providers, preferably in collaboration with extension services, should improve agricultural knowledge and innovation system management software to avoid technostress among farmers (Hansen et al., 2020).

The results in Table 8 show that if Croatian agronomists had the opportunity to receive training in digital agriculture, they would use this training to participate in mandatory administrative tasks for state institutions ($F = 3.142$, $df = 2$, $P < 0.05$), to use applications in order to update the company website ($F = 12.034$, $df = 2$, $P < 0.01$), to develop software according to the specific functional needs of the company (e.g. for production planning, optimisation of fertilisation, optimisation of crop protection) ($F = 3.280$, $df = 2$, $P < 0.05$), to follow technological changes in digital agriculture ($F = 7.379$, $df = 2$, $P < 0.01$), to become familiar with the basic rules and possibilities of electronic commerce ($F = 12.447$, $df = 2$, $P < 0.01$), to be able to handle programmes for data storage and transfer (databases, cloud, data transfer) ($F = 8.690$, $df = 2$, $P < 0.01$), to become familiar with the legal and ethical aspects of using digital tools (ICT) ($F = 7.051$, $df = 2$, $P < 0.01$), to become familiar with the methods of data collection, processing and storage ($F = 12.326$, $df = 2$, $P < 0.01$), to be able to select the necessary and optimal information for decision-making ($F = 4.819$, $df = 2$, $P < 0.01$) and to be able to pass on the necessary knowledge or organise training for teamwork in the company in a digital environment ($F = 5.927$, $df = 2$, $P < 0.01$). Agronomists who completed their education in the last ten years and ten to twenty years ago are more likely to agree with the statement about the benefits of additional training in digital agriculture than those who completed their education more than twenty years ago (Table 8).

Agronomists who consider the digitalisation of Croatian agriculture necessary and useful are more likely to agree with the statement that the knowledge of digital technologies in agriculture is equally important for medium-sized and large farms, as well as for cooperatives, clusters and state units. According to the results in Table 9, a statistically significant difference was found between the statements regarding medium farms ($F = 4.975$, $df = 3$, $P < 0.01$), large farms ($F = 5.513$, $df = 3$, $P < 0.01$), cooperatives ($F = 5.326$, $df = 3$, $P < 0.01$), clusters ($F = 4.410$, $df = 3$, $P < 0.01$), local ($F = 6.269$, $df = 3$, $P < 0.01$), regional government units ($F = 4.054$, $df = 3$, $P < 0.01$), and agencies and ministries ($F = 2.876$, $df = 3$, $P < 0.05$), with regard to the digitalisation of Croatian agriculture.

In their qualitative study, Linsner et al. (2021) analysed the perspective of 52 German farmers and concluded that the interviewed farmers have a balanced opinion on improvements in their field of work. Small and medium-sized farmers agree that digitalisation in agriculture, especially automated precision farming, is helpful for farming within complex parcel boundaries resulting from the small-scale and fragmented land structure in rural Germany, and that office work is also changing in terms of meeting the reporting obligations towards authorities. The farmers interviewed also mentioned negative aspects such as lack of knowledge, lack of availability, high prices that are not affordable to owners of small and medium-sized farms, and lack of support from machine and software developers.

Table 8. Analysis of variance for the variable possibility of additional training in the field of digital agriculture according to the year of completion of agronomists' final level of education

The possibility of additional training in the field of digital agriculture	Year of completion of the highest level of education						*F*	*P*
	<10		10 - 20		> 20			
	M	SD	M	SD	M	SD		
Familiar with the possibilities of various software tools in digital agriculture	4.08	1.023	3.68	1.249	3.33	1.397	2.422	0.096
Familiar with various IT hardware needed for digital agriculture	3.70	1.285	3.48	1.295	3.07	1.335	1.312	0.275
Familiar with different machinery for precision agriculture	3.90	1.194	3.68	1.345	3.20	1.373	1.645	0.200
Familiar with the use of sensors in agriculture as well as their installation, operation and maintenance	3.90	1.236	3.40	1.323	3.07	1.580	2.497	0.089
Able to assist with mandatory administrative tasks to government institutions	3.95	1.108	3.56	1.356	3.07	1.100	3.142	0.049*
Able to use applications to update the company website	3.95	1.154	3.56	1.387	2.13	1.125	12.034	0.000**
Able to develop software according to the specific functional needs of the company	3.75	1.565	3.08	1.552	2.60	1.724	3.280	0.043*
Able to follow technological changes in digital agriculture and the latest trends	4.25	0.981	3.60	1.225	3.00	1.309	7.379	0.001**
Familiar with the basic rules and possibilities of e-commerce	4.05	1.061	3.28	1.242	2.47	0.834	12.447	0.000**
Skilled in handling programmes for data storage and transfer	3.98	1.209	3.44	1.325	2.40	1.242	8.690	0.000**
Familiar with the legal and ethical aspects of using digital tools (ICT)	3.78	1.250	2.96	1.274	2.47	1.246	7.051	0.002**
Familiar with the methods of data collection, processing and storage	4.13	1.067	3.04	1.338	2.53	1.246	12.326	0.000**
Able to select the required and optimal information for decision-making	4.10	1.033	3.44	1.294	3.07	1.486	4.819	0.011**
Able to pass on the necessary knowledge or organise training for teamwork in the company in a digital environment	4.13	1.017	3.24	1.300	3.20	1.320	5.927	0.004**

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

This is in line with the study by Bolfe et al. (2020) on 504 Brazilian farmers, whose challenges related to digital framing are mainly related to the investment and cost of digital technologies (purchase, upgrade or services) (67.1%), lack of connectivity in rural areas (47.8%), the value of hiring specialized service providers (44.0%) and lack of knowledge about which technologies they should use in their farm (40.9%). A similar analysis is conducted in the United States, Canada, Europe, Australia, Brazil, China, Iran and Tanzania and shows that the main barriers pointed out by farmers are related to the costs associated with digital technologies and services, reliable internet, training and knowledge about digital agriculture (Ruder, 2019; Erickson and Deboer, 2020; Shang et al., 2021; Pesci et al., 2023; Kitole et al., 2024). For this reason, many universities are creating new study programs specifically designed for future agricultural experts, animal scientists, food experts, and plant scientists, rather than computer science students, to provide relevant training in Agriculture 4.0 (Catal and Tekinerdogan, 2019; Várallyai and Szilágyi, 2021; Akramovich, 2022). To enable the development of Agriculture 4.0 alongside the development of new educational programmes, it is necessary to train supply chain actors and raise awareness among farmers so that they can take full advantage of the benefits of digital agriculture (Scuderi et al., 2022).

Table 9. Analysis of variance for the variable importance of knowledge about digital technologies in agriculture according to the digitalisation of Croatian agriculture

	Digitalisation of Croatian agriculture									
	Necessary		Useful		Neither		Both		*F*	*P*
	M	SD	M	SD	M	SD	M	SD		
Small farms	3.67	1.414	2.71	1.083	2.33	1.155	3.34	1.180	2.566	0.061
Medium farms	4.22	0.972	3.04	1.083	2.33	1.155	3.80	1.091	4.975	0.003**
Large farms	4.67	0.707	3.63	0.970	2.67	1.528	4.36	1.080	5.513	0.002**
Large (industrial) producers	4.78	0.667	4.21	1.021	4.00	1.000	4.61	0.722	1.971	0.125
Cooperatives	4.67	0.707	3.67	1.090	2.33	0.577	4.14	1.002	5.326	0.002**
Clusters	4.44	0.882	3.75	1.073	2.33	1.528	4.23	0.985	4.410	0.006**
Local government units	4.78	0.667	3.46	1.215	2.00	1.000	3.95	1.077	6.269	0.001**
Regional self-government units	4.78	0.667	3.63	1.135	2.67	1.528	4.05	1.077	4.054	0.010**
Agencies and ministries	4.78	0.667	4.00	0.933	3.33	1.155	4.36	0.917	2.876	0.042*

M = mean; SD = standard deviation; ** $P \leq 0.01$; * $P \leq 0.05$

In order to realise the full potential of digitalisation in the agri-food sector, governments need to create a trustworthy environment as well as protective laws and regulations. Agricultural policy has the challenging task of ensuring that digitalisation occurs in an ethical, equitable and inclusive manner, and collaboration between research centres, digital innovation hubs, start-ups and technology companies should be encouraged to improve the flow of knowledge and innovation (MacPherson et al., 2022; Sadjadi and Fernández, 2023). It is very important to organize cooperation between universities, which need to restructure the education of bachelor's and master's graduates to meet the new realities of modern production, and organizations that develop digital technologies so that college graduates are able to work in new conditions (Khudyakova et al., 2023).

This preliminary study on the competence, perspective and potential role of agronomists in the digitalisation of agriculture in Croatia is a contribution to the literature because, to our knowledge, this is the only study in Croatia that examines the role and importance of agronomists in the adoption of new technologies in agriculture. However, based on the results, it is clear that it is necessary to conduct such studies to obtain information on the opinions of agronomists in order to improve the awareness and adaptation of digital agriculture. It is also important for economic and educational policymakers in order to be able to create new educational programs to train the future generation of agronomists in the field of digital agriculture. Before drawing any conclusions, we should mention some limitations of the study. Future research should focus on a larger sample of respondents, investigate additional impacts of digital agriculture and willingness to adopt innovation systems in production and examine the role of agronomists and farmers from different production entities.

In addition, studies could focus on investigating the intensity and impact of the learning curves associated with new educational programs for digital agriculture, thus driving the development of educational modules that can provide a stronger sense of the necessity and effectiveness of change.

CONCLUSIONS

The application of digital technologies in agricultural production is a major challenge but at the same time an inevitable change for all stakeholders in the agriculture and food production sector. A prerequisite for successful digitalisation is the education and competence of all stakeholders, from local and regional authorities, farmers and agronomists to traders, sellers and even consumers. While knowledge of digital technologies is equally important for medium and large farms, as well as for government entities, transferring this knowledge to small and medium-sized farmers necessitates a well-structured process to ensure sufficient access to training and the adoption of new technologies. Adequate infrastructural and financial resources, combined with focused efforts to build skills and competencies, are essential for the advancement of digital agriculture, especially in rural areas. The main conclusions that can be drawn from this research are: 1. Agronomists are the central figures and are sufficiently competent to lead the digitalization of agriculture; 2. Faculties, extension services, the Chamber of Croatian Agronomists, along with software and digital equipment distributors and producers, should play a key role in providing additional training in digital skills.

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