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Effect of farmer's age and level of education on the degree of adoption of precision technologies in sheep farms

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Abstract: This study analyzes the impact of age and education level on the awareness and information behavior of 270 sheep farmers in Bulgaria during the 2024 - 2025 period. The results demonstrate a significant information gap, as nearly 49% of the respondents are unfamiliar with precision livestock farming (PLF) technologies. Demographic indicators emerge as a leading factor in digital readiness - the highest levels of awareness and active behavior are observed among young farmers under 40 years old (46 %) and those with higher education (61.29 %), who combine three or more information sources. Conversely, among farmers over 61 years old and those with primary education, over 54 % are unfamiliar with these technologies, relying only on traditional channels or showing a complete lack of interest in innovation. Bridging this gap requires targeted training strategies to turn technology into a tool for economic sustainability. Similar demographic trends and barriers to innovation are also observed in neighboring countries - Serbia, Romania, and Turkey, where farmer aging and low digital literacy remain common regional challenges.

Keywords: sheep farming; precision livestock farming (PLF); Balkan region

INTRODUCTION

Within the context of global challenges relating to climate change, resource scarcity and increasing demands for animal welfare, the implementation of sensors, software systems and automation is becoming a critical factor for the competitiveness of the sheep farming sector (Vukanović, 2018; Eastwood et al., 2021). Despite the technological potential, the transition to smart sheep farming in Bulgaria is characterized by tangible heterogeneity and a number of systemic limitations. Bachev (2020) identified a serious gap between technological capabilities and their real application on a national level, caused by specific macroeconomic factors and institu-

tional instability. Markov et al. (2022) added that Bulgaria ranks second to last in the EU according to the Integrated Digital Economy and Society Index for 2021, and not a single municipality in the country has yet developed a strategy for the implementation and development of digital technologies in agriculture. The systemic constraints in Bulgaria are not an isolated case, but a part of a larger regional and global divide. Bridging this “digital divide” requires not only a state strategy, but also targeted information security that will transform technologies from a tool for control into a means of economic survival and sustainability for Bulgarian sheep farmers. This digital transformation is developing at different speeds, with regional specificities in the Balkans contrast-

ing sharply with global technological trends. A similar situation is observed in the neighbouring countries. In Serbia, sheep farming is concentrated mainly in the central and eastern mountainous regions, where small, traditional farms predominate (Mičić et al., 2020). However, the sector suffers from “structural gaps” caused by the aging of farmers and the demographic decline in rural areas, leading to the abandonment of pastures and reduced competitiveness (Group, 2018; Milićević et al., 2025). In North Macedonia, significant fluctuations in animal numbers and a shift from dairy to meat production are observed, but outdated infrastructure and low productivity remain major obstacles to innovation and the implementation of precision technologies (Bunevski et al., 2016). In a broader regional context, Turkey leads the way with 26% of the total sheep population in the region, but still faces a significant “technology gap” in the transition to smart management (Canan, 2023). In Greece and Romania, efforts are focused on overcoming geographical barriers and transferring knowledge through international networks to improve animal health and fertility (Ocak, 2019; Simitzis et al., 2021). At the European Union level, sheep farming remains one of the most conservative sectors, with only 4.35 % of farms actively using digital data for management decisions (Lima et al., 2018; Vaintrub et al., 2020). However, on a global scale, technologies such as virtual fences, digital farm twins, and artificial intelligence for early disease diagnosis are increasingly being introduced (Arshad et al., 2024; Arulmozhi et al., 2024; Issa et al., 2024).

The objective of the present study is to examine the effect of age and level of education on the degree of adoption of precision technologies in sheep farming in Bulgaria and the region.

MATERIALS AND METHODS

For the purposes of the scientific research, a survey was conducted in the period 2024 - 2025, covering 270 farmers from the sheep farming sector in different regions of the country, with different productive directions. The collection

of empirical data was carried out using the direct standardized interview method, applied in a face-to-face form using the PAPI format (paper questionnaire). The use of a unified questionnaire and strict adherence to the sequence of questions guaranteed a high degree of objectivity and comparability of the results.

For the needs of statistical analysis and graphical presentation, the studied indicators were grouped into specific classes. The demographic profile of the respondents was distributed into three age categories: up to 40 years, from 41 to 60 years and over 61 years. The educational qualification was classified in a similar way, divided into three levels: higher, secondary and primary education.

Special attention was paid to the information behaviour and the degree of familiarity with the concept of „Precision Livestock Farming“ (PLF). The preferred sources of information (social networks and the Internet, thematic gatherings/exhibitions, companies and scientific units) were analyzed, as well as the intensity of their use, grouped according to the number of simultaneously used channels: one, two or three and more sources.

For basic statistical processing of the data and preparation of the graphs, the MS Excel package was used.

RESULTS AND DISCUSSION

The distribution of farmers depending on their awareness of the concept of „Precision Livestock Farming“ (PLF) is presented on Fig. 1. Only 32.59 % stated that they were familiar with this concept, 48.89 % indicated that they were not familiar at all, and 18.52 % were partially familiar.

Our data is supported by a study by Bachev (2020), according to which 49.4 % of Bulgarian farmers stated that they were not at all familiar with PLF systems, and only 14.2 % of farms in the country actually use some form of a digital technology at the moment.

The results about the low level of awareness among sheep farmers are also directly confirmed

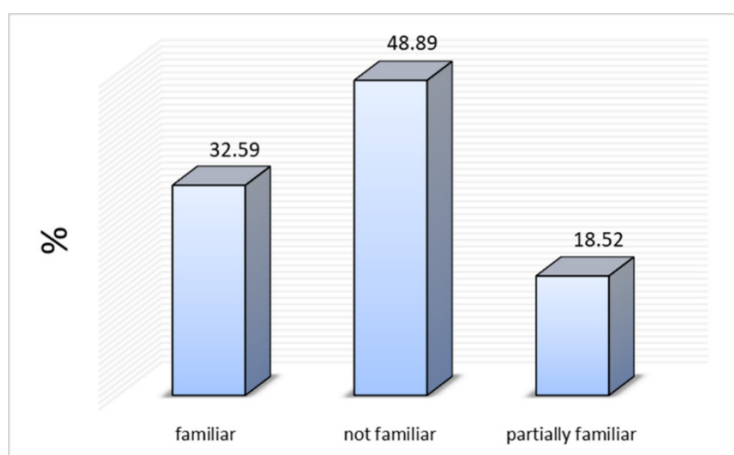


Figure 1. Distribution of farmers according to what extent there are aware of the precision livestock farming concept, %

Source: Authors' own elaboration

by international studies, which reveal similar levels of technological skepticism in the small ruminant sector. In the general European framework, data from the Sm@RT project covering France, Italy, Ireland, Norway, the United Kingdom, Estonia, Hungary and Israel show that only 35 % of the farmers use specialized herd management software (Delanoue, 2022). These findings are complemented by a study by Lima et al. (2018) among 2000 farmers, classifying just over half of them (50.5 %) as “non-adopters” – a group characterized by a complete lack of intention to implement innovations due to misinformation and perception of technologies as an administrative burden. This global skepticism and unawareness is often explained by the low economic value per animal unit and the prevailing conservative profile of farmers in the sector (Morgan-Davies et al., 2019; Vaintrub et al., 2020).

Similar levels of low awareness are observed in countries neighboring Bulgaria. In Romania, a significant gap exists between sensor usage (45 %), and the adoption of comprehensive herd management software (18 %) (Caja et al., 2020; Paolino et al., 2025). The main hurdle for modernization is the lack of information. 36 % of farmers identify limited knowledge as a barrier to adopting new technologies, especially in extensive small ruminant production (Ciliberti et al., 2024;

Stępień et al., 2023). A study in the Çanakkale region (Turkey) found that levels of awareness were even lower – only 8 % of farmers stated that they were “very familiar” with the term “Precision Animal Farming”, and 84 % confirmed that they did not use or were not interested in any digital tools (Aydin et al., 2020). A similar situation was observed in Serbia, where limited familiarity with digital solutions and artificial intelligence has been identified as a major barrier to the modernization of the sector (World Food and Agriculture – Statistical Yearbook 2024). In their study, Marku et al. (2024) found that in North Macedonia and Albania the lack of state training strategies left farmers without information about innovations, and Bojkovski (2015) added that low levels of subsidies in the sector further discouraged farmers from seeking and learning about the possibilities of modern technologies.

The distribution of farmers by age depending on the level of awareness of the precision animal farming is presented on Fig. 2. The highest percentage of farmers familiar with the concept was reported among the youngest, up to 40 years old – 46 %, and 36 % were not familiar, respectively. Conversely, the oldest group of farmers, over 61 years old, reported the lowest percentage of those familiar with it – 18.87 % and the highest percentage of those unfamiliar with it – 54.71 %.

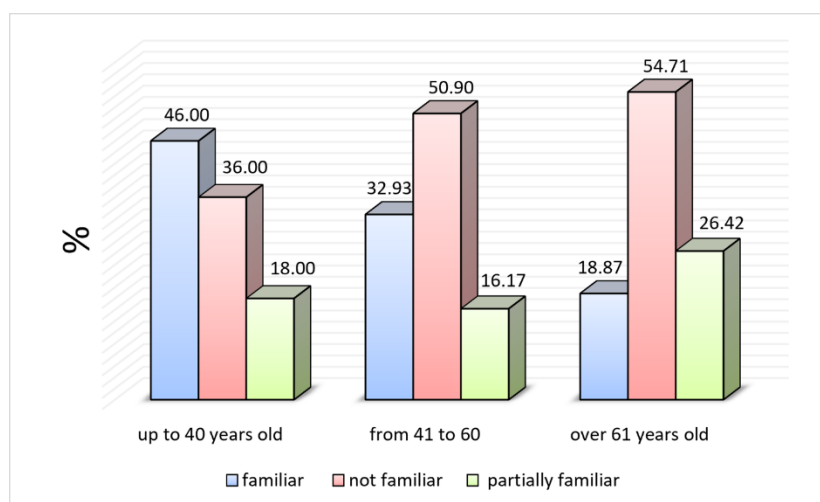


Figure 2. Distribution of farmers by age depending on their level of awareness with the precision animal farming concept, %

Source: Authors' own elaboration

The results obtained are supported by the research of Sarov et al. (2024). The authors found that in Bulgaria, young managers under 40 years of age formed the group with the highest “innovation activity”, while farmers over 60 years of age had the lowest level of awareness and interest. This picture is even more clearly expressed in Romania, where Stoian et al. (2022) found that informational interest in digitalization was concentrated in a critically narrow range – as many as 53.8 % of farmers with active interest were between the ages of 18 and 30. A similar agrarian model and demographic challenges were observed in neighbouring Serbia. There, the average age of farmers is 59 years, which, according to Erdei-Gally and Vágány (2022) is one of the main reasons for the slow absorption of new knowledge and technologies. The researchers emphasized that conceptual misunderstanding of the principles of work is a more serious barrier to innovation than the lack of technical equipment itself. On a broader European scale, Rakun et al. (2022) found that the probability of adopting even basic awareness with precision technologies decreased proportionally with the increase of age. This progressive decline in awareness is explained by the higher technological literacy of the younger generations, who naturally accept digital solutions as

the standard for modern farming (Angyalos et al., 2021). Thus, age emerges not simply as a biological factor, but as a major informational boundary to the digital transformation of the sector.

The distribution of farmers by groups, according to level of education and level of awareness of the precision animal farming concept is presented on Fig. 3. Farmers with higher education have the highest percentage of those familiar with the concept – 61.29 % and 35.48 % are not familiar. Among farmers with primary education – only 17.02 % stated that they were familiar and 65.96 % were not familiar.

The data obtained are supported by the study by Masi et al. (2022), which established a clear relationship between education and awareness for precision technologies. Farmers with higher level of education demonstrated a significantly higher level of knowledge of precision farming concepts compared to those with lower level of education.

This was also confirmed at a regional level, where Bulgaria and Romania were cited as lagging behind in the digitalization of agriculture in the EU, precisely due to the lack of digital literacy among strata with lower level of education. The situation is similar in Serbia, where Gavrilović et al. (2025) noted that despite the secondary level of education among 58.5 % of farmers, the actual

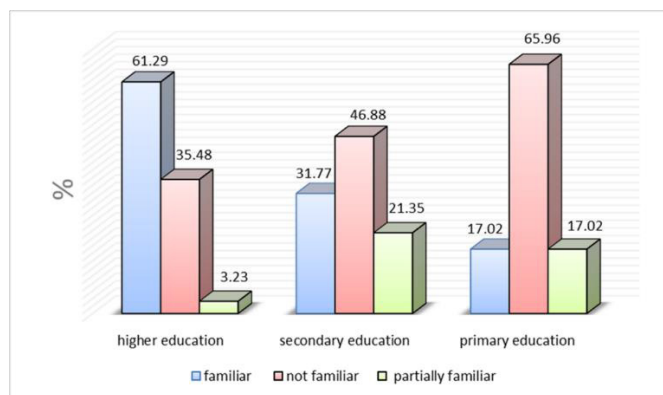


Figure 3. Distribution of farmers by groups according to level of education and level of awareness with the precision animal farming concept, %

Source: Authors' own elaboration

use of PLF technologies remained critically low (only 15 %). In this regard, Vidas-Bubanja et al. (2023) added that the education system often remained focused on traditional methods, neglecting IT skills. The problem is even more serious in Macedonia and Albania, where the deficit is not only among farmers, but also in the lack of information literacy at the institutional level, which makes their training almost impossible due to the lack of qualified personnel (Basha et al., 2014). Against this background, in Turkey, Güldal et al. (2025) found that it is university education that is the key variable that separates “potential users” of smart technologies from the rest, since higher education there directly correlates with a higher propensity for innovation and risk-taking.

Fig. 4 presents the distribution of farmers depending on what sources of information they use, regarding the introduction to precision technologies in sheep farming. The largest percentage of farmers use social networks and the Internet as a source of information – 59.63 %. With almost the same percentage are thematic gatherings and exhibitions – 49.26 % and companies from the agricultural sector occupy 48.15 %. With the smallest share is the source of scientific units – 24.44 %, and 28.15 % of farmers have declared that they are not interested in precision technologies at all.

The results obtained about the leading role of the Internet and personal contacts (thematic gath-

erings/exhibitions) find serious support in studies on the Balkan region. In Bulgaria, the studies of Sarov et al. (2024) found that over 46 % of farmers relied primarily on discussions with relatives, colleagues and visits to thematic gatherings to obtain information. In parallel, Bachev (2020) highlighted the growing importance of the digital environment, citing the Internet and media as some of the most influential channels for knowledge transfer, used by 68.8 % of farmers. The dependence on technologies is even more pronounced in Serbia. A study by Radović et al. (2021), conducted in the Nišava County, found

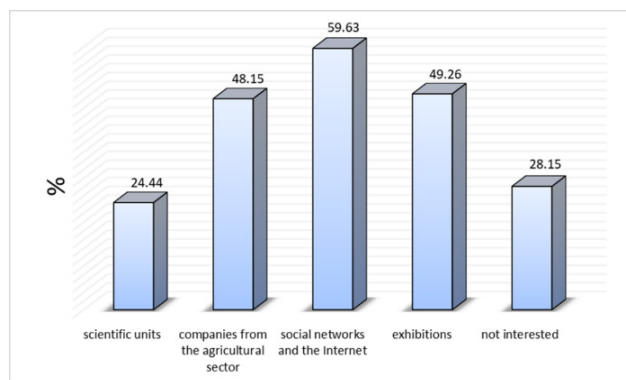


Figure 4. Distribution of farmers depending on the use of various information sources on precision livestock technologies, %

Source: Authors' own elaboration

that between 86.6 % and 93.3 % of farmers used television and electronic media for gaining professional information. The authors added that in certain municipalities the share of farmers who trusted specialized agricultural websites reached the impressive 96.6 %. In contrast to these results is the situation in North Macedonia, where significantly lower trust in digital platforms is observed. According to Trajkovski (2024), farmers in the Pelagonia region rated the reliability of social media with a relatively low 2.14 out of 5 points, preferring instead direct contacts and traditional methods of communication. The author pointed out that the lack of systematic state information campaigns forced producers to seek information mainly from colleagues and private consultants.

Similar structural deficits are also observed in Romania, where Salih (2021) highlighted the acute shortage of advisory services from official scientific units. This forced farmers to turn to private sources, innovation clusters (such as IND AGRO WEST) or directly to specialized equipment suppliers. This pattern of increased reliance on informal sources is even more pronounced in Turkey. Eryilmaz et al. (2020), in a study conducted in Samsun province, found that the Internet is now used by 47.1 % of dairy farmers, but television remained the most preferred mass media channel for knowledge dissemination (87.1

%). The dominant sources of information here are also family members (72.9 %) and neighboring farmers (67.1 %). Over half of the farmers (51.5 %) refused to participate in trainings, because they believed that they already had enough information, or relied entirely on the experience shared by their colleagues (27.3 %)

The distribution of farmers using different sources of information depending on their age is presented on Fig. 5. Among young farmers, up to 40 years old, 62 % stated that they used 3 or more sources of information. Only 8 % stated that they were not interested. Among the oldest farmers, over 61 years old, the opposite is true – 60.38 % stated that they were not interested and only 24.53 % used 3 or more sources of information.

Similar conclusions were reached by Miteva et al. (2025). They found that 88.3 % of farmers relied on personal meetings and contacts with other farmers as the main source of information. These farmers tend to adopt new methods only after seeing their success in real conditions on a neighbouring farm, making the “colleague” the most reliable source. A similar situation is observed in North Macedonia, where personal contacts are preferred over digital ones by older farmers, and trust in colleagues is significantly higher than in social media (Trajkovski, 2024). This leads to a “low search” strategy among older farmers, who trust only a narrow circle of

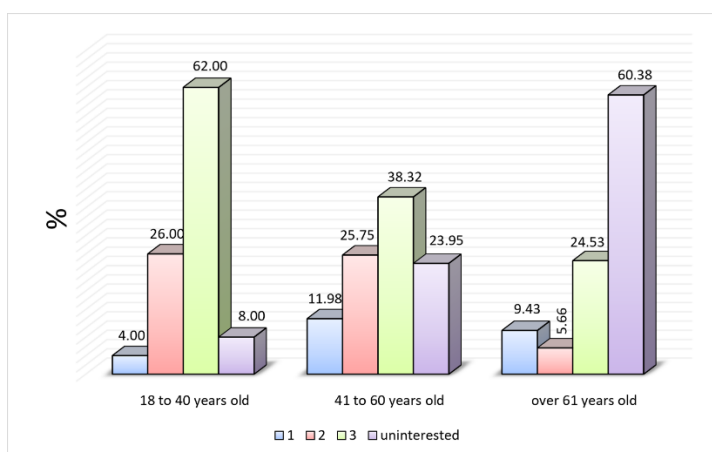


Figure 5. Distribution of farmers using different number of information sources depending on their age, %

Source: Authors' own elaboration

acquaintances. Romania shows even more extreme values than Bulgaria in terms of the “sole source”. According to Beck et al. (2021), 89.6 % of older Romanian farmers rely only on their practical experience, and Jurjević et al. (2019) added that access to the Internet among them was below 50 %. The situation is similar in Turkey, where the leading source of information is television (93.3 %), while the Internet is used by only 39.2 % of farmers (Akdemir et al., 2021). Among older people, decisions are rarely made independently, with information being supplemented by “family help” in 30 % of cases. In Serbia, the number of sources directly depends on age, 27 % of young farmers (20 - 25 years old) combine professional contacts with online communities on a daily basis, while for people over 65 this share drops to 10 % (Bálint and Lengyel, 2021). Digital isolation is most noticeable in Serbian rural areas, where less than 2 % of households over 56 use a computer, which limits access to information sources other than personal meetings (Jurjević et al., 2019). The situation is similar in Greece, where farmers often combine between two and three traditional sources, but rarely include modern tools. More than two thirds of them trust consultants (78.4 %), the experience of colleagues (77.5 %) or television and newspapers (73.3 %). Despite the use of several parallel channels, the Internet is present in the

information mix of only 13.1 % of Greek farmers (Genius et al., 2013).

The percentage of farmers using different numbers of information sources by groups depending on their education is presented on Fig. 6. Among farmers with higher education, 70.97 % use information from 3 or more sources. This percentage gradually decreases, as among farmers with secondary education it is 41.67 %, and among those with primary education it is only 12.76 %. An inverse relationship is observed with respect to education and the “uninterested” group: the highest percentage of uninterested farmers is reported among those with primary education – 57.45 %, followed by those with secondary education – 23.96 %, and the least uninterested are farmers with higher education – 9.68 %.

The results are supported by research by Király et al. (2023), according to which educated farmers in Bulgaria actively use digital channels to access information on subsidies, market prices, and innovations, making them the most likely group to combine more than three sources in decision-making. Conversely, low-educated groups in the country show a strong dependence on traditional media and personal contacts, which makes them significantly more vulnerable to disinformation.

Similar data were demonstrated in a research for Serbia. Ilić-Kosanović et al. (2019) found that farmers with higher education perceived

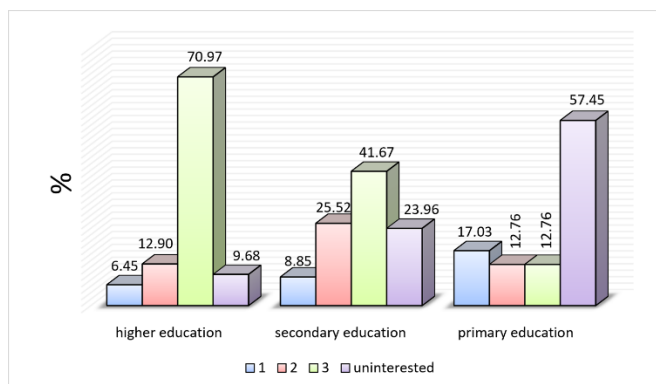


Figure 6. Percentage of farmers using various sources of information depending on their level of education, %

Source: Authors' own elaboration

and interpreted new information faster, using at least two different sources. At the same time, Dimitrijević and Stojić (2019) explained that their less educated colleagues relied almost entirely on television and informal conversations, often showing disinterest in modern technological channels.

Salih (2020) found that in Romania, the lack of specialized education, basic communication skills or command of foreign languages limited many farmers to local and informal sources. In this regard, Fieldsend et al. (2017) added that farmers with a higher level of education acted as “active innovators”, while those with primary education remained “passive followers”, who mostly imitated the practices of their neighbours. In North Macedonia, the choice of information channels depends directly on the educational level of farmers. According to Trajkovski (2024), more educated farmers mainly trusted official advisors (4.21/5), and actively combined various sources to check the reliability of data. In contrast, farmers with lower education relied mainly on social networks and personal contacts, although they themselves rated them as less reliable. Among farmers with higher education in Turkey, there is a direct correlation with the active use of more than 3 sources of information, such as the Internet, specialized publications and private consultancy services (Boz and Özçatalbaş, 2010). This group, managing larger farms, combines digital channels with professional assistance from veterinary specialists and agronomists (Boz and Budak, 2015). Conversely, farmers with lower level of education are limited to a single traditional source – mainly television (over 90% of cases) or informal advice from family and neighbours (Akdemir et al., 2021).

CONCLUSION

Age and education remain leading factors for farmers' awareness and their digital preparedness. The study shows that nearly half of farmers (49 %) are not familiar with precision technologies, which reveals a serious information gap

in the sector. The highest awareness and active behaviour are demonstrated by young farmers under 40 (46 %) and those with higher education (61.29 %), who combine three or more data sources (digital channels, companies and scientific units). Conversely, among farmers over 61 and those with primary education, the share of those unfamiliar is over 54 %, with their choice being limited to single traditional channels or a complete lack of interest in innovations. Bridging this gap requires targeted training strategies that turn technologies into a means of economic sustainability for farms. These demographic specificities and systemic barriers to innovations are also observed in neighbouring countries in the region - Serbia, Romania, and Turkey, where the aging of farmers and low digital literacy emerge as a common regional challenge.

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