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Farmers' perceptions of precision agriculture technologies as a path towards climate change mitigation

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Abstract

Climate change is a significant global challenge, affecting food system, human health and future generations. The adaption and mitigation are linked to sustainable practices such as adopting precision agriculture. In Bulgaria, the issues connected with climate change have led to the necessity of agriculture transformation and implementation of adaptation measures. Observing farmers' attitudes and willingness to adopt practices like precision farming is essential for enhancing agricultural resilience. This study explores Bulgarian farmers' perceptions of climate change and the role of precision technologies in mitigation efforts. The paper is based on a survey of sixty farmers in South Bulgaria. The study results indicate that producers are well-informed about precision technologies and their potential and benefits. The majority of the farmers are aware of climate change's serious impact on agriculture and the crucial role precision farming plays in addressing these challenges. Therefore, a targeted government policy is vital for promoting innovation and precision technologies in Bulgarian agriculture.

Keywords**:** digitalization, precision technologies, climate resilience, adaptation strategy

INTRODUCTION

Climate change is considered the main global challenge that affects human health and food security (IPCC, 2014; Wang *et al*., 2020). Several studies outlined that climate change will continue to has a negative impact worldwide (Wang *et al*., 2020; Antwi-Agyei & Nyantakyi-Frimpong, 2021). The extreme weather events will affect agricultural productivity, exacerbating poverty and insecurity among farmers (Arbuckle *et al*., 2013). Adaptation practices play a vital role in farmers' resilience and mitigation of the adverse effects of climate change (Ali & Erenstein, 2017). However, climate adaptation is complex and depends on various factors, such as farmers' perceptions, adaptation strategies, and the challenges in implementations (Esfandiari *et al*., 2020). In addition, multiple drivers, including social, demographic and institutional factors, can significantly influence successful adaptation (Wang *et al*., 2020).

The Eurobarometer survey report (2023) shows that climate change is a serious global problem for 77% of the citizens of the EU. The perception of climate change as the most significant global issue varies across different countries. It is most common in Sweden (41%), followed by Denmark and the Netherlands, while it is least prevalent in Latvia (4%), as well as Romania and Bulgaria (6%). Across the EU, the highest levels of concern about the issue are seen in Malta (93%) and Greece (90%). The lowest levels of concern are observed in Estonia (45%) and Czechia (48%). In Bulgaria, 65% of the respondents consider the problem as serious one. However, compared to the average of the EU-27, the level of awareness and engagement are lower.

Climate change has increasingly affected crop yields, water availability, and soil conditions. Therefore, precision agriculture has emerged as an opportunity to utilise advanced technology for optimization of agricultural inputs and to mitigate environmental impacts. Understanding farmers' perceptions of climate change and willingness to adopt precision agriculture is crucial for developing policy and supporting climate change mitigation (Chen *et al.*, 2024).

Georgieva *et al*. (2022) highlighted that Bulgaria is considered a high-risk region for floods and wildfires. In addition, the country is under a moderate risk of earthquakes, water shortages, and extreme heat. Therefore, adaptation and mitigation strategies are crucial to overcoming the climate change challenges in Bulgaria. A number of studies (Slavova & Kazandjiev, 2004; Eitzinger *et al*., 2008; Kazandjiev, 2011; Kazandjiev *et al*., 2015) have observed the influence of climate change on Bulgarian agriculture and potential solutions. In addition, Atanasova & Naydenov (2025) highlight the driving forces behind the obstacles and barriers to climate adaptation in Bulgaria.

Some authors stated that there is a link between farmers' concerns about climate change and their adoption of precision agriculture. Producers who acknowledged climate change as a significant risk are more likely to look for adaptive strategies and improve resilience (Arbuckle *et al*., 2013). Precision technologies provide solutions for climate change mitigation by increasing resource efficiency, reducing greenhouse gas emissions, and improving soil health (Tey & Brindal, 2012).

The adoption of precision technologies in Bulgaria is low, and the topic is not thoroughly discussed in scientific literature. According to a survey conducted by the Ministry of Agriculture regarding development of digitalization strategy in agriculture, nearly 90% of farmers do not use digital technologies, and only 30% plan to invest in the coming years (Ministry of Agriculture, 2018). Climate change's rising challenges emphasize the necessity of Bulgarian agriculture for adaptation and mitigation strategies. Therefore, understanding farmers' attitudes and willingness to adopt sustainable practices, such as precision farming technologies, is essential for improving the sector's resilience.

The study aims to outline Bulgarian farmers` perceptions of climate change and the effect of various precision technologies as adaptation and mitigation measures.

MATERIALS AND METHODS

Based on the literature review, a survey related to climate change awareness and precision technologies adoption was developed. The methodological framework use similar approach as Chen *et al*. (2024). The survey is based on an online survey conducted from November to December 2024. A total number of sixty-five questionnaires were collected, from which sixty were validated. The study is focused on three main topics: (1) socio-demographic characteristics of the respondents; (2) awareness of climate change impact and precision technologies; and (3) farmers` perceptions and assessment. Socio-demographic characteristics variables are also presented (Table 1).

The second and third sections of the questionnaire utilize 5-point Likert scales for measurement. Data was gathered through an online survey, where respondents were informed about the survey's details and provided their consent in accordance with the General Data Protection Regulation (GDPR) of the European Union.

RESULTS AND DISCUSSION

Literature background

Precision technologies can contribute to achievement of goals related to climate change challenges by optimizing resource use, while minimizing environmental impacts, primarily by reducing greenhouse gas emissions (Balafoutis *et al.,* 2017). A number of studies outlined the linkages between the awareness of climate change impact and the implementation of precision technologies. According to Lane *et al.* (2018), climate change attitudes affect adoption decisions. However, their influence is lower than farm profitability, market and labor conditions, and regulations. Furthermore, the willingness to adopt differs significantly and depends on farm characteristics and perceptions of extreme weather. The role of gender in this aspect could be irrelevant. Some studies show that women are more likely to implement sustainable practices based on more substantial environmental concerns and beliefs (Druschke & Secchi, 2014; Ferto & Bojnec, 2024). In contrast, other studies (Ndiritu, 2014; Pilarova *et al*., 2018) noted that gender is a minor factor.

Table 1. Variables of the model

Variables	
Respondents characteristics	
Age	Years
Education	1 – below primary
	2 – primary
	3 – high school
	4 – undergraduate
	5 – graduate
	0 – Other
Number of children	Number
Gender	0 – female, 1– male
Marital status	Unmarried – 0
	Widowed –1
	Divorced – 2
	Civil partnership – 3
	Married – 4

Source: Labelling of variables is according to Chen et al. (2024)

Younger farmers are more interested in implementing new digital technologies and tools and are more interested in investing in innovations and new digital opportunities (Lichtenberg, 2004; Vecchio *et al*., 2020). On the other hand, older farmers have barriers to adopt precision technologies due to their limited awareness and deeply rooted traditions (Prokopy *et al.*, 2019). Education is a critical driver for precision agriculture decisions. Producers with higher education are more likely to adopt sustainable agricultural practices, because they are more interested in searching and exploring information about environmental benefits (Barbercheck *et al*., 2014; Gemtou *et al.*, 2024). In addition, education is associated with climate awareness, which positively influences adoption of precision technologies (Prokopy *et al*., 2019).

Farm size and specialization are other important factors that are key determinants in adoption decisions. Larger farms have reduced costs and higher returns on investment when adopting sustainable practices are more interested in implementing advanced technologies and innovations (Michels *et al.*, 2020). Furthermore, farms with higher incomes have a better financial capacity to invest in this area (Prokopy *et al*., 2019; Walder *et al*., 2019).

The benefits for environment due to precision agriculture implementation, especially the potential to mitigate greenhouse gas emissions, remains unexplored to a certain extent. A survey indicated that improved environmental quality is essential for adopting precision technologies (Watcharaanantapong *et al.*, 2014). However, there is a lack of studies assessing precision agriculture's impact beyond the farm level (Zarco-Tejada *et al.*, 2014).

Pierpaoli *et al.* (2013) collected data from various surveys and identified the key factors that influenced adoption of precision agriculture. These factors are divided into three main groups: (1) competitive and contingent factors, (2) socio-demographic factors, and (3) financial and economic factors.

Based on the literature review, it can be concluded that farmers are crucial stakeholders whose decisions affect climate change mitigation and reduction of global greenhouse gas emissions. The adoption of precision technologies as a path towards sustainability and climate neutrality is related to overcoming barriers. Therefore, analyzing the factors for adoption, awareness, perspectives and perceptions of farmers are the key steps towards capacity, skills-building and implementation of sustainable agriculture.

Farmers' perceptions of climate change and precision agriculture technologies adoption

Climate change significantly impacts crop yields, water resources, and soil quality. As a response, precision agriculture has become an important approach and by implementing advanced technology enhances resource efficiency and reduces environmental effects. Identifying Bulgarian farmers’ awareness, attitudes, and perceptions is a key element in mitigating the effect of climate change and implementing sustainable agricultural practices.

The study's results can be divided into three directions. The first part outlines farmers' characteristics (Table 2), while the second discusses producers' awareness of climate change and precision technologies. The third aspect of the survey explores the attitudes and assessments of potential of precision farming for climate change mitigation. Respondents` characteristics include age, gender, education and marital status. The survey covers the South Central Region of Bulgaria. Gender structure is dominated by men (64.8%).

The sample results show a relatively young age structure with an average age of 37, with the oldest respondent being 64 and the youngest – 18 years.

Regarding education, the results that respondents have a bachelor's degree, since none of them have a primary or lower education. A high level of education suggests that participants are well-informed about current global challenges, including climate change. In households, the predominant trend is having either no children or one child. Furthermore, the combination of a high level of education and the fact that many respondents are young suggests they have access to information about new technologies and trends in agriculture. The distribution of the respondents by marital status shows that most of the farmers are married or live in civil partnerships.

Based on the additional questions, it can be concluded that the farmers represent all sectors of agriculture - 30% of the respondents are grain producers, followed by vegetable farmers with 26.7%. Livestock specializations form 20% of the sample.

The second and third groups of the survey aim to investigate farmers’ awareness of precision farming technologies and the effects of climate change.

The farmers' responses clearly show that most producers are aware of the main impact of climate change on agriculture (Figure 1). Only 3.3% stated that they were somewhat informed about the issue. The most frequently mentioned adverse effects and risks related to climate change are droughts, floods, and forest fires. These results correspond with data of Georgieva *et al.* (2022) who reported that Bulgaria in under a high risk for floods and wildfires.

Table 2. Descriptive statistics of the sample

Indicators	**Age**	**Education**	**Number of children**	**Marital status**
Mean	36.58824	4.088235	0.794118	2.470588235
Standard Deviation	13.28503	0.712131	0.880062	1.673959091
Minimum	18	3	0	0
Maximum	64	5	3	4
Count	60	60	60	60

Source: Own survey

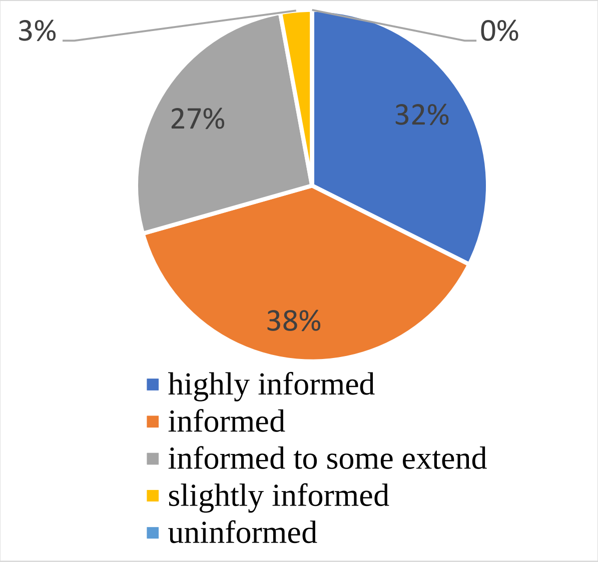

Figure 1. Level of awareness and information about the impact of climate change on agriculture
Source: Own survey

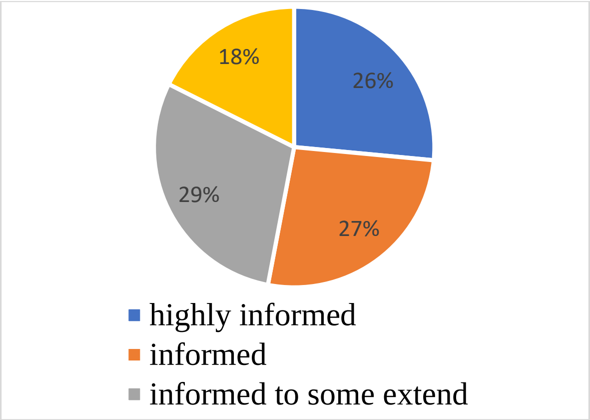

Figure 2. Level of awareness and information about precision technologies (5%)
Source: Own survey

Another key element of the survey is associated with the awareness and information about precision technologies (Figure 2). The results indicate a positive trend since significant percentage of farmers are familiar with precision farming technologies – 30% are highly informed, and 23.3% are informed. An encouraging fact is that no farmer is unfamiliar with these technologies.

The result is not surprising, considering the large percentage of young farmers among respondents, as well as the high share of people with higher education, which suggests better access to information and readiness to adopt new technologies. These trends correspond with the results reported by Barbercheck *et al*. (2014) and Gemtou *et al*. (2024).

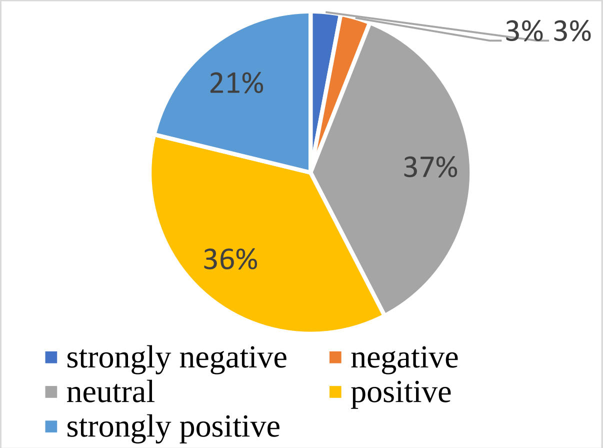

Figure 3. Assessment of the impact of precision technologies on climate change mitigation (%)
Source: Own survey

The third group of questions is related to the farmers' perceptions of precision technologies' potential to reduce pressure on environment and climate change mitigation (Figure 3). Because farmers are well-informed about climate change and precision technologies, most of respondents assess these effects as strongly positive or positive (58%). Another interesting trend is that 36% of participants view the impact of precision farming on climate mitigation as neutral. Probably, precision farming is associated with digitalization rather than sustainability and climate change combat.

In addition, the study includes farmers' assessment of the potential of precision technologies to improve the agriculture climate resilience (Figure 4). The results show that 70% of respondents stated that precision agriculture, to a large extent or a relatively large extent, will lead to agriculture resilience.

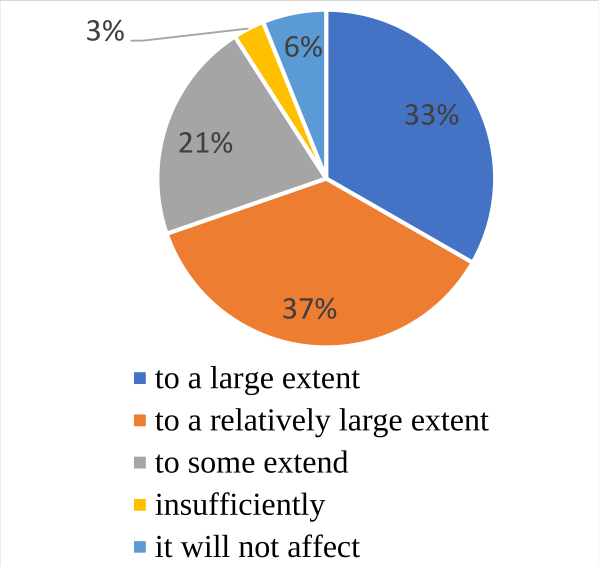

Figure 4. Assessment of the impact of precision technologies on agriculture climate resilience (%)
Source: Own survey

At the same time, there is a very small percentage of negative opinions, with only 3% of participants who consider that these technologies will not affect agriculture. The trends correspond to the study of Roy & George (2020) who considered precision farming a step towards sustainable, climate-smart agriculture.

The last group of questions relates to the link between precision agriculture and SDG13-Climate action. The results show that 73% of farmers believe that precision technologies will improve the management of climate change policies (Figure 5). In comparison, 67% consider integration of climate change measures into national strategies and policies as a positive step towards implementing precision technologies. In addition, 68% believe that enhanced financial commitment to support climate policies is a benefit of precision farming.

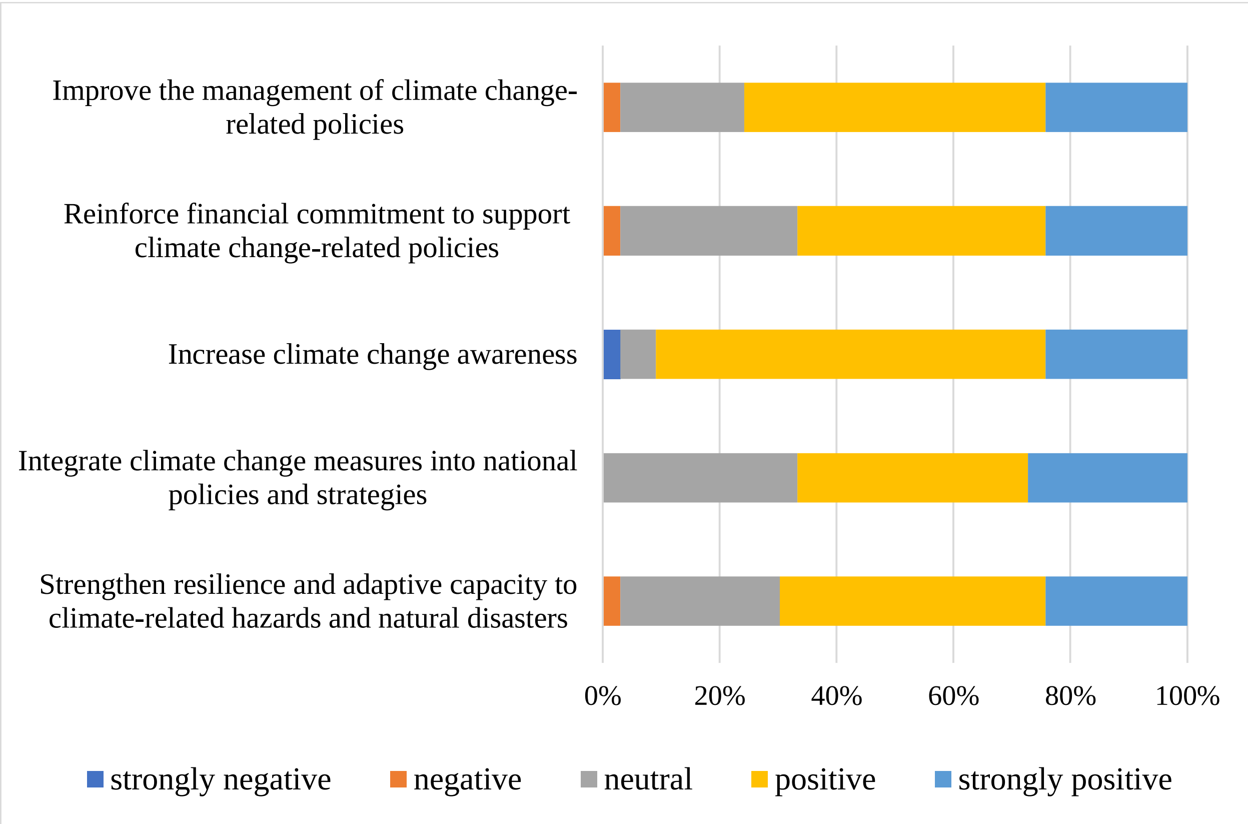

Figure 5. Assessment the impact of precision technologies on following objectives relative to SDG13 - Climate Action (%)-5-point Likert scale
Source: Own survey

CONCLUSIONS

Climate change is a significant challenge that affects the food system and poses risk to food security and human health. It continues to impact crop yields, water and soil. Therefore, precision agriculture has become an important option because advanced technology enhance resource efficiency and reduce greenhouse gas emissions and environmental pressure. The current study conducted among sixty farmers in Bulgaria's South Central region, highlights the adoption of precision technologies and their potential benefits in mitigating climate change. The findings indicate that most respondents are well-informed about precision agriculture and its prospects. A strong link is observed between farmers' knowledge, education level, and age, influencing their perception of precision farming's potential to address climate change. Most farmers acknowledge the significant impact of climate change on agriculture, identifying droughts, high temperatures, and floods as the primary challenges they face.

Although many farmers recognize the environmental benefits of precision technologies the adoption of precision agriculture in Bulgaria remains limited. Therefore, a targeted state policy is essential for promoting innovation and the use of precision technologies in Bulgarian agriculture. To achieve this, both national funding and financial support under the CAP and Horizon Europe could be viable options. The successful implementation of new technologies and enhanced digitalization requires better institutional coordination to ensure the effective execution of proposed measures.

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REFERENCES

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Clim. Risk Manag*. 16, 183–194. https://doi.org/10.1016/j.crm.2016.12.001

Antwi-agyei, P., & Nyantakyi-frimpong, H. (2021). Evidence of climate change coping and adaptation practices by smallholder farmers in northern Ghana. *Sustainability*, 13, 1308. https://doi.org/10.3390/su13031308

Arbuckle, J. G., Morton, L. W., & Hobbs, J. (2013). Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: evidence from Iowa. *Clim. Chang*. 118, 551–563. https://doi.org/10.1007/s10584-013-0700-0

Atanasova, A., & Naydenov, K. (2025) Perceptions of the Barriers to the Implementation of a Successful Climate Change Policy in Bulgaria. *Climate*, 13, 40. https://doi.org/10.3390/cli13020040

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Van der Wal, T., Soto, I., Gómez-Barbero, M., Barnes, A., & Eory, V. (2017). Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability*, 31, 9(8), 1339. https://doi.org/10.3390/su9081339

Barbercheck, M., Brasier, K., Kiernan, N.E., Sachs, C., & Trauger, A. (2014). Use of conservation practices by women farmers in the northeastern United States. *Renew. Agric. Food Syst.*, 29(1), 65–82. https://doi.org/10.1017/S1742170512000348

Chen, R., Su, Y., & Tran, L. (2024). Small Farmer's Perceptions of Climate Change and Adoption of Climate Smart Practices: Evidence from Missouri, USA.

Sustainability, 16, 9525. https://doi.org/10.3390/su16219525

Druschke, C.G., & Secchi, S. (2014). The impact of gender on agricultural conservation knowledge and attitudes in an Iowa watershed. *J. Soil Water Conserv.*, 69, 95–106.

Eitzinger, J., Thaler, S., Orlandini, S., Nejedlik, P., Kazandjiev, V., Vucetic, V., Sivertsen, T.H., Mihailovic, D.T., Lalic, B., & Tsiros, E. (2008). Agroclimatic Indices and Simulation Models. In *Survey of Agrometeorological Practices and Applications in Europe, Regarding Climate Change Impacts, Copisteria Sangallo: ESF, COST:* Brussels, Belgium, 734, 15–114.

Esfandiari, M., Mirzaei Khalilabad, H. R., Boshrabadi, H. M., & Mehrjerdi, M. R. Z. (2020). Factors influencing the use of adaptation strategies to climate change in paddy lands of Kamfiruz. Iran. *Land Use Policy,* 95, 104628. https://doi.org/10.1016/j.landusepol.2020.104628

Ferto, I., & Bojnec, Š. (2024). Empowering women in sustainable agriculture. *Sci. Rep.*, 14, 7110.

Gemtou, M., Kakkavou, K., Anastasiou, E., Fountas, S., Pedersen, S. M., Isakhanyan, G., Erekalo, K. T., & Pazos-Vidal, S. (2024). Farmers' Transition to Climate-Smart Agriculture: A Systematic Review of the Decision-Making Factors Affecting Adoption. *Sustainability*, 16, 2828.

Georgieva, V., Kazandjiev, V., Bozhanova, V., Mihova, G., Ivanova, D., Todorovska, E., Uhr, Z., Ilchovska, M., Sotirov, D., & Malasheva, P. (2022). Climatic Changes—A Challenge for the Bulgarian Farmers. *Agriculture*, 12, 2090. https://doi.org/10.3390/agriculture12122090

Kazandjiev, V. (2011) Climate change, Agroclimatic Resources and Zonning of Agriculture in Bulgaria. J. *Balk. Ecol.*, 14(4), 365–382.

Kazandjiev, V., Degorski, M., Błazejczyk, K., & Georgieva, V. (2015). Agroclimatic Conditions in Bulgaria and Agriculture Adaptation. *Europa XXI*, 29, 23–42.

Lane, D., Chatrchyan, A., Tobin, D., Thorn, K., Allred, S., & Radhakrishna, R. (2018). Climate Change and Agriculture in New York and Pennsylvania: Risk Perceptions, Vulnerability and Adaptation among Farmers. *Renew. Agric. Food Syst.*, 33, 197–205.

Lichtenberg, E. (2004). Cost-responsiveness of conservation practice adoption: A revealed preference approach. *J. Agric. Resour. Econ.*, 29(3), 420–443. http://dx.doi.org/10.22004/ag.econ.30920

Michels, M., von Hobe, C.-F., Musshoff, O. A (2020). A trans-theoretical model for the adoption of drones by large-scale German farmers. *J. Rural Stud.*, 75, 80–88. https://ui.adsabs.harvard.edu/link_gateway/2020JRurS..75...80M/doi:10.1016/j.jrurstud.2020.01.005

Ministry of agriculture (2018). *Strategy for the digitalization of agriculture and rural areas of the Republic of Bulgaria.* https://www.mzh.government.bg/bg/politiki-i-programi/politiki-i-strategii/strategiya-za-cifrovizaciya-na-zemedelieto-i-selskite-rajoni-na-/

Ndiritu, S.W., Kassie, M., & Shiferaw, B. (2014). Are There Systematic Gender Differences in the Adoption of Sustainable Agricultural Intensification Practices? Evidence from Kenya. *Food Policy,* 49(P1), 117–127. https://doi.org/10.1016/j.foodpol.2014.06.010

Pierpaoli, E., Carli, G., Pignatti, E., & Canavari, M. (2013). Drivers of precision agriculture technologies adoption: a literature review. *Procedia Technology*, 8, 61-69.

https://doi.org/10.1016/j.protcy.2013.11.010

Pilarova, T., Bavorova, M., & Kandakov, A. (2018). Do Farmer, Household and Farm Characteristics Influence the Adoption of Sustainable Practices? The Evidence from the Republic of Moldova. *Int. J. Agric. Sustain.*, 16(4/5), 367–384. http://dx.doi.org/10.1080/14735903.2018.1499244

Prokopy, L.S., Floress, K., Arbuckle, J.G., Church, S.P., Eanes, F.R., Gao, Y., Gramig, B. M., Ranjan, P., & Singh, A. S. (2019). Adoption of Agricultural Conservation Practices in the United States: Evidence from 35 Years of Quantitative Literature. *J. Soil Water Conserv.*, 74(5), 520–534. https://doi.org/10.2489/jswc.74.5.520

Roy, T., & George, K. J. (2020). Precision Farming: A Step Towards Sustainable, Climate-Smart Agriculture. In: Venkatramanan, V., Shah, S., Prasad, R. (eds) Global Climate Change: Resilient and Smart Agriculture. Springer, Singapore. https://doi.org/10.1007/978-981-32-9856-9_10

Slavov, N., & Kazandzhiev, V. (2004). Phytoclimatic estimation of air temperature transitions across characteristic boundary values in Bulgaria. 2003. In *Proceedings of the Conference on Water Observation and Information System for Decision Support (BALWOIS)*, Ohrid, Macedonia, 25–29 May 2004, 33.

Special Eurobarometer 538 Report (2023). Climate Change. Retrieved from https://europa.eu/eurobarometer/surveys/detail/2954

Tey, Y. S., & Brindal, M. (2012). Factors influencing the adoption of precision agricultural technologies: a review for policy implications. *Precision agriculture*, 13, 713-730. http://dx.doi.org/10.1007/s11119-012-9273-6

Vecchio, Y., De Rosa, M., Adinolfi, F., Bartoli, L., & Masi, M. (2020) Adoption of Precision Farming Tools: A Context-Related Analysis. *Land Use Policy* 2020, 94, 1-8. https://dx.doi.org/10.1016/j.landusepol.2020.104481

Walder, P., Sinabell, F., Unterlass, F., Niedermayr, A., Fulgeanu, D., Kapfer, M., Melcher, M., & Kantelhardt, J. (2019). Exploring the Relationship between Farmers' Innovativeness and Their Values and Aims. *Sustainability* 2019, 11(20), 5571. https://doi.org/10.3390/su11205571

Wang, T., Teng, F., & Zhang, X. (2020). Assessing global and national economic losses from climate change: a study based on CGEM-IAM in China. *Clim. Chang. Econ.*, 11(3), 2041003. https://doi.org/10.1142/S2010007820410031

Watcharaanantapong, P., Roberts, R. K., Lambert, D. M., Larson, J. A., Velandia, M., English, B. C., Rejesus, R. M., & Wang, C. (2014). Timing of precision agriculture technology adoption in US cotton production. *Precision agriculture*, 15, 427-446. https://doi.org/10.1007/s11119-013-9338-1

Zarco-Tejada, P., Hubbard, & N., Loudjani, P. (2014). Precision agriculture: an opportunity for EU farmers - potential support with the cap 2014-2020. *Joint Research Centre (JRC) of the European Commission. Monitoring Agriculture Resource S (MARS) Unit H04*, Brussels, Belgium.