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Climate Change Perception and Innovative Mitigation Practices Adopted by Hungarian Farms

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Abstract

Climate change is becoming a growing concern for the agricultural sector. Variable weather events, such as droughts and floods, are expected to have a significant negative impact on agricultural losses, earnings and consumption. The agriculture industry in Europe is not immune to these difficulties. This study focuses on Hungary, a country with a strong agricultural focus that, as a result, is particularly susceptible to climate change. An exploratory factor analysis (EFA) was performed to synthesis data about the perspectives of Hungarian farmers on the dangers of climate change. Then, latent variables were employed as explanatory variables in the Logit model to investigate the link between the perceptions of climate change risks by Hungarian farmers and their inclination to adopt innovative ways to mitigate its repercussions. Changes in temperature and precipitation, economic damage, water damage, and insect damage are seen as the most serious repercussions of climate change by Hungarian farmers. These beliefs raise the possibility of adopting new strategies to offset harmful consequences, including (i) the adoption of new varieties, (ii) ice and frost protection, and (iii) the use of agro-meteorological data. The results show that the chance of adopting new varieties is substantially influenced by farmers' assessments of harm caused by pests, pathogens, and illnesses (2.91***). In contrast, water damage concerns seem to have a significant impact on the adoption of novel approaches to reduce cold and frost damage (2.18***). This study's findings support the efforts of stakeholders and policymakers to encourage the dissemination of technology to protect crops from climate change in Hungary and imply that governments should provide financial incentives to farmers to boost innovation uptake.

Keywords

Climate change, agriculture, farmers, practices, innovation, perception.

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Introduction

Over the last few centuries, human-caused activities such as fossil fuel combustion and widespread deforestation have resulted in an increase in atmospheric greenhouse gas (GHG) concentrations, resulting in major climate change over the globe (Di Vita et al., 2017; Gudmundsson et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) reveals that the year 2019 experienced the highest CO_2 levels in two million years and reported in its fifth assessment report that the global average temperature has been growing since 1880 and is anticipated to continue to do so (IPCC, 2021). Additionally, from 2011 to 2020, the average global surface temperature increased by 1.09 degrees Celsius over pre-industrial levels (IPCC, 2021). Consequently, climate change (CC) has become one of the world's most perplexing and difficult topics today (Zhu et al., 2021). Indeed, it has long been recognized as a major worldwide issue (Yokomatsu et al., 2020) that poses significant threats to social, ecological, and economic well-being (O'Neill et al., 2020).

This emergency has been recognized as such by several international organizations and Intergovernmental agencies. The United Nations framework convention on climate change defined it as "a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time" (Sands, 1992).

Within all human production activities, agriculture is considered one of the sectors most vulnerable to the effects of climate change due to its reliance on natural resources and climate (Spina et al., 2021). It is constantly impacted by climate change through extreme weather events, unanticipated temperature and rainfall variations, all of which pose considerable threats to the agro-economy (Nicita et al., 2020).

This results in decreasing agricultural yields (Raimondo et al., 2021), disrupted food supply networks, higher food prices and lower food quality (Edenhofer et al., 2011).

By 2050, adverse effects on agricultural yields and farmer livelihoods are anticipated to result in a 20% rise in the worldwide population of hungry people (Hossain et al. 2019). Although climate change affects the whole world (Lobell et al., 2017), declining yields exacerbate the food insecurity of smallholders in developing countries (Huong et al., 2017), whose livelihoods are entirely dependent on climate (Wang et al., 2017).

The European agriculture sector is not exempt from this concern, being one of the world's major food producers; climate change's impact on agriculture varies by place, depending on the direct effects of changing climatic conditions on agricultural productivity as well as the indirect repercussions of increasing pest and disease pressure (Olesen et al., 2011).

Given the importance of such topic and considering little deepening of climate change effect on the agricultural economies of EU eastern countries, this study focused on Hungary, whose economy mainly reliant on agriculture.

Suffice it to say that Hungary's agriculture, forestry, and fisheries sector is worth $5221 million, up from $3591 million in 2000 (FAO, 2020). It is currently considered a moderately vulnerable country to the impacts of climate change. But long-term analyses show a considerable increase in climate risk, particularly an increased hazard of drought during summer and seasonal flooding, water stagnation and erosion as the result of augmented frequency of extreme events (Ladanyi et al., 2009).

Among other ways for addressing these issues, efforts are being undertaken to enhance climate resilient agriculture using integrated pest management and precision agriculture (Ahmed et al., 2018), as well as by adjusting cropping schedules and selecting new crop varieties (Amare and Simane, 2017).

That the effects of climate change have a negative impact on agricultural activities and farm profitability (Jamil et al., 2021) is a well-known issue, yet the perception of climate change in Eastern European Union countries has been little investigated by researchers. Given that perception of change is the most important factor in climate change adaptation, this study aims to investigate the effect that perception of climate change has on the likelihood of Hungarian farmers adopting innovative techniques to mitigate its impacts.

To fill this gap in the literature, it estimated the willingness of Hungarian farmers to introduce innovative tools and techniques on their farms.

Furthermore, according to several scholars, the more you believe in the idea of climate change, the more likely you are to adjust your actions to the projected outcomes (Syropoulos and Markowitz, 2022).

In light of these premises, this paper intends to address the following research questions:

RQ1: What, in the opinion of Hungarian farmers, are the most significant effects of climate change on the agricultural productivity?

RQ2: Are agrometeorological data considered useful tools to reduce the negative impact of climate change on Hungarian farms?

RQ3: How likely is it that these effects will prompt Hungarian farmers to use climate change adaptation tools like new warm and floods resistant crop varieties?

RQ4: How likely is it that these effects will prompt Hungarian farmers to use climate change adaptation tools like ice and frost protection in cold seasons?

RQ5: Do the socio-economic characteristics (education level) of Hungarian farmers affect the possibility that they will adopt climate change adaptation tools?

Literature review

Farmers' perception of climate change

Several studies have examined farmers' perceptions of climate change (Brown et al., 2018) and their impact on the development of appropriate farm management measures (Singh, 2020).

Most of the extant research on farmers' perceptions and reactions to climate change either investigates their future possibility of adopting a practice or they are already adopted (Niles et al., 2015).

Current research indicates that farmers are generally aware of climate change, especially in terms of severe weather events and their influence on agriculture at the local level (Timpanaro et al., 2013), even if, one of the primary issues with climate change, however, is that threats are often seen as physically and temporally remote (Spence et al., 2011). In this direction, some scholars (Arbuckle et al., 2015) argue that farmers make sense of climate and weather changes and develop adaption methods based on their own observations and experiences on their own properties. For instance, Spence et al. (2011) and Schattman et al. (2016) found that prior exposure to floods, air pollution, or other severe weather events enhanced farmers' anxiety about climate change.

The scientific literature, however, reveal a discrepancy between farmers' beliefs and adaptive actions (Nguyen et al., 2019). This discrepancy could be caused by the uncertainty in understanding and forecasting future weather and climate change (Ricart et al., 2018), and/or by the likelihood of adaptation, which varies according to a variety of factors, including socioeconomic characteristics (Stringer et al., 2020). Nevertheless, some authors (Huong et al., 2017) assert that many farmers may be unaware of climate change issues due to a variety of factors, among others, the level of education, age, farm size, and income.

Innovative adaptation strategies

Several adaptation methods that are both accessible and effective in strengthening farm-level resilience have been found, and they are now being disseminated to the agricultural community (Di Vita et al., 2015a). These include the use of new technologies to adapt to climate change, such as the deployment of more robust crop varieties; plant disease protection; agro-meteorological forecasting; and crop protection against cold and frost (Di Vita et al., 2015b).

Adaptation techniques are often long-term reactions to climate change's consequences and include making adaptations to the increased internal risks imposed by the phenomenon (Helling et al., 2015).

The IPCC (2014) defined adaptation as "the process of adapting to actual or projected climate and its effects; in human systems, adaptation seeks to moderate damage or exploit beneficial opportunities; in natural systems, human intervention can facilitate adaptation to projected climate and its effects".

Farmers have evolved a range of coping methods to deal with weather unpredictability, which are short-term tactics designed to mitigate exposure to shocks (Lolig et al., 2019).

Since the capacity to make credible predictions in advance is a critical component of any agricultural system, the availability of a sufficient agro-meteorological database is a prerequisite for studying and managing agricultural production processes. Agrometeorological parameters are crucial for making day-to-day and seasonal farm management decisions as well as mitigating climate change risks in agriculture, as they guide the actions mandatory to transform and further reorient agricultural systems to effectively support development and ensure regional food security in a changing climate (Singh et al., 2009). For instance, in precision agriculture, it is key to be able to forecast future situations and estimate changes in biophysical crop responses because of these environmental oscillations. Forecasting is particularly critical for risk minimization in agricultural systems, which depend on empirical data and process-based models to simulate the uncertainty associated with unknown data (Allen, 1994). Additionally, wireless sensor networks have developed as a potent technology for data collecting and processing in the agricultural sector in recent years (Borgia, 2014), enabling agrometeorological information systems to function with a range of affordable, high-performance, and dependable sensors (Mirhosseini et al., 2017).

Nowadays, modern agriculture has recognized the fundamental need of having and using agro-meteorological data for effective agricultural operations. For example, air temperature is often regarded as the primary climatic variable that controls the pace of vegetative and reproductive growth (Sawan, 2018). Thus, having access to this variable enables the application of appropriate therapies in real time, allowing for profitable agricultural production regulation and catastrophe risk reduction operations (Reznik et al., 2017).

Frost is another weather hazard that perennial crop farmers must contend with. As a result, future estimates of frost risk have been highlighted as beneficial for long-term planning efforts (Parker et al., 2019). Frost exposure also places a geographical limitation on plants' bioclimatic niches and may be a limiting factor for agricultural output in temperate areas worldwide (Maracchi et al., 2005).

Perennial crops progressively harden and become more vulnerable to cold temperatures when temperatures increase in early spring, increasing their sensitivity to frost damage. Abnormally mild weather in late winter or early spring may also accelerate phenology, resulting in a false spring in which crops emerge from dormancy and begin their yearly growth earlier than usual, increasing the risk of frost damage.

Any divergence from ideal growth circumstances, such as excessive or insufficient rainfall, excessive or insufficient warmth, increased cloudiness or abrupt wind, or hailstorms, may influence yields in both rain-fed and irrigated crops (Gobin, 2018). For example, Del Toro et al. (2015) discovered that dryness during the growth season and excessive rainfall during the harvest season are the two climate-related variables that historically have had the largest detrimental influence on production.

The development of protection strategies, such as hail and frost nets, aerators, and heating equipment, to combat ice and frost damage can be considered an important factor for Hungary, which has a continental climate with harsh winters.

Climate change may result in severe weather events, which may influence agricultural productivity, as well as pests and illnesses (Adamo et al., 2012). These severe phenomena include protracted droughts, prolonged periods of torrential rain and very high temperatures (Rosenzweig et al., 2001).

Moreover, global warming has a significant impact on insect life in a variety of ways: changes in population growth rates; increases in the number of generations of insects; geographic range expansion (Kiritani, 2013); introduction of species to alternative host plants; increased risk of invasion by migrating insects; overwintering insects (Bale et al., 2002); movement of pests from lower to higher latitudes (Barzman et al., 2015).

Ectothermic insects are the least vulnerable to climate change and global warming because they can swiftly adapt to changing environmental circumstances. This provides them with an edge in terms of aggressive reproduction, hence increasing their danger to agricultural productivity (Ferrer et al., 2014). Additionally, climate change is extremely likely to modify insect pests and the connection between the host and the bug (Bale et al., 2002), reducing agricultural yield. Certain crops that are known to be insect pest resistant may become sensitive to pest damage and react positively to pest damage because of climate change and global warming (Reddy, 2013).

High temperatures may impact an insect's growth and development at various phases of its life cycle (Zhang et al., 2015), as well as its fecundity and mortality (Khaliq et al., 2014). For instance, when impacted by warmer circumstances, insects that have acclimated to high temperatures may be able to increase the number of generations each year (Van Dyck et al., 2015). Furthermore, as temperatures rise, infections might travel to new locations with vulnerable hosts, influencing disease development (Etterson and Shaw, 2001). Hence, developing more climate-resilient agricultural production systems is the right way to deal with climate change.

Improvements in crop varieties have been discovered to assist growers to respond to increased drought frequency and changing insect populations. Indeed, developing new varieties that are more resistant to drought and heat stress while maintaining the same production potential should help mitigate some of the predicted climate change consequences (Cairns et al., 2013).

In this context, the introduction of novel cultivars in Hungary, which suffers from summer dryness, is an important adaptation strategy for Hungarian agricultural output.

Crop variety changes have been shown to enable farmers to address climate change, including higher drought frequency (Yu and Babcock, 2010), changed insect populations, extended growing seasons and other variables (Harvey et al., 2014).

To alleviate the effect of climate change on agricultural systems, one strategy is to produce superior varieties that are genetically tolerant or resistant to a new spectrum of abiotic and biotic stresses. Crop improvement needs access to novel gene variations (Kilian et al., 2021).

Adaptation in the form of improved varieties, trading patterns, and crop mixtures has been shown to be beneficial in mitigating the effects of climate change (Aisabokhae et al., 2011). Adopting drought-tolerant maize cultivars would provide adaptive advantages by preventing major output redistribution (Malcolm et al., 2012).

Numerous modifications, such as advancing planting dates or spreading new crop kinds, may be implemented reasonably rapidly by individual farmers in reaction to observable consequences.

While emerging technologies like as genome editing may aid in the focused development of superior cultivars, public perception and legislative concerns continue to limit their successful usage (Vindigni et al., 2022).

In light of this context, the current study aims at investigating which perceived effect of climate change affect the adoption of some important innovative adaptation techniques by Hungarian farmers.

Materials and methods

Data collection

A semi-structured questionnaire was developed to determine how perceptions of the negative effects of climate change influence the likelihood that Hungarian farmers will implement innovative techniques.

Survey was carried out in three different steps. Firstly, a survey was designed by analyzing main contribution of literature about climate change effects on the agriculture, thus also examining the specificity of Eu eastern European countries. This exploration was also associated with the analysis of existing tools and innovative agricultural practices to face and reduce negative effects of climate change. Secondly a questionnaire was designed to collect data and information and explore the farmers intention to face climatic change and introduce adaptive innovations in their agricultural practices.

Subsequently an interview survey, based on farmers statements, was carried out between 2017 december and 2018 february. Data collection was administered by staff members of the Hungarian FADN through face-to-face setup. Responses were recorded online using Google Form platform.

The 300 farms that made up this study's sample was a sub-sample of the 2171 sample holdings that were chosen for data collection as part of the 2017 Farm Accountancy Data Network (FADN) framework. The FADN sample is representative of the agricultural holdings larger than 4-thousand-euro Standard Output. In 2017 this population was made up of 108 thousand individual and 7664 corporate holdings (Keszthelyi and Kis Csatári, 2019). This study took a sub-sample from the FADN sample using convenience sampling method; therefore, the sample of 300 farms used for this study's statistical analysis cannot be considered representative of the whole population. The questions were meant to evaluate the key climate change adaptation strategies that farmers believed may prevent unfavorable climatic factors.

Specifically, **the first section** was designed to analyze farmers' views of climate change because of climatic variability in terms of average temperature rise and effect on production cycles. In this regard, they were asked whether "*the weather in my agricultural area has become significantly more variable over the past year*" or "*average temperatures have clearly increased during crucial production cycle periods*" or "*annual rainfall has clearly decreased during crucial production cycle periods*".

The **second section** was designed to evaluate farmers' perspectives on climate change and its probable effects on crop productivity and farm profitability. In this respect, respondents were questioned, "Due to the change in climatic conditions, the profitability of my farm has decreased" or "*Due to the change in climate conditions, the quality of my crops has decreased*" or "*Which of the consequences of a changing climate have been felt on the farm?*". Each item was ranked on a 5-point Likert scale ranging from 1 ("*I do not agree/not at all*") to 5 ("*I agree completely/very lot*").

The third section aimed at collecting main socio-demographic data of farmers, such as age (24-72 years), education, and gender (Table 1), and structural characteristics of farms (Table 2), such as farm type, ownership type and geographical position of farms.

	Freq.	%
Gender		
Male	257	85.67
Female	43	14.33
Tot.	**300**	**100.00**
Manager's education		
None	15	5.00
Vocational tranining	78	26.00
Skilled worker	114	38.00
Plant engineer	75	25.00
Agriculture engineer	18	6.00
Tot.	**300**	**100.00**

Source: authors'eleboration

Table 1: Farmer's socio-demographic data.

Type of farms	Freq.	%
Fruits	116	38.67
Horticultural	123	41.00
Vineyard	61	20.33
Tot.	**300**	**100.00**
Ownership type		
Sole proprietorship	282	94.00
Limited liability company (LLC)	18	6.00
Tot.	**300**	**100.00**
Geographical position of farms		
Great Plain	29	9.67
Transdanube	105	35.00
Northern Hills	166	55.33
Tot.	**300**	**100.00**

Source: authors'eleboration

Table 2: Farms structural characteristic.

Data analysis

To synthesize the information about Hungarian farmers' perception on climate change damages an exploratory factor analysis (EFA), with an orthogonal rotation (varimax) of 0.6 was used (Hamam et al., 2022a; Raimondo et al., 2022). The descriptive statistics of each variable are shown in Table 3.

Then, latent factors will be employed as explanatory variables in the Logit model to examine the effect that perception of risks due to climate change has on the propensity of Hungarian farmer to adopt innovative techniques to mitigate climate change damages.

Table 4 shows the descriptive statistics of the innovative techniques considered in this study, such as: i) use of new warm and floods crop varieties, ii) ice and frost protection and iii) use of agrometeorological data.

The coefficients derived from the EFA were included into the logit model, and they were employed as covariates to examine the likelihood of Hungarian farmers to adopt novel strategies to offset the consequences of climate change.

Three linear equations were established for the three explored novel techniques: the adoption of new varieties, ice and frost protection, and the use of agrometeorological data.

Since the dependent variable in our regression equations is a dummy variable assuming the value 0 or 1, the Logit estimator was used in this investigation.

$$\mathrm{INNOV_i} = \alpha + \beta \, perceived\_cc\_eff_i + v \, manag\_edu_i + \varepsilon_i \qquad i = 1, 2 \ldots 300 \qquad (1)$$

where for each of the three equations, INNOV is the dependent variable that corresponds to one of the three innovative techniques investigated (i.e. use of new varieties, ice and frost protection and use of agrometeorological data), while α is

Variables	Description	Item	Mean	Std. Dev.
K1	1 - 5 Likert scale	The weather became volatile	3.35	1.31
K2	1 - 5 Likert scale	The average temperature has risen	3.37	1.27
K5	1 - 5 Likert scale	The quality of my produce has deteriorated	2.68	0.85
K6	1 - 5 Likert scale	Yields have fallen	2.86	0.93
K9b	1 - 5 Likert scale	Soil degradation by water	2.02	1.14
K9d	1 - 5 Likert scale	Waterlogging	2.61	1.21
K9e	1 - 5 Likert scale	Flood	1.40	0.82
K9h	1 - 5 Likert scale	Emergence of new pests	2.94	0.98
K9i	1 - 5 Likert scale	Emergence of new pathogens and diseases	2.91	0.97

Note: 1 - strongly disagree; 5 - strongly agree.
Source: authors'eleboration

Table 3: Perception variables.

Variables	Type	Item	Mean	Std. Dev
INNOV_1	Dummy (0-1)	Use of new warm and floods crop varieties	0.82	0.38
INNOV_2	Dummy (0-1)	Ice and frost protection	0.25	0.43
INNOV_3	Dummy (0-1)	Use of agrometeorogical data	0.81	0.39

Note: 0 - I don't want to apply; 1- I've already adapted or I intend to apply in the next 5-10 years.
Source: authors'eleboration

Table 4: Adaptation practices variables.

the intercept of the equations and β is a vector of perceived climate change effects.

The degree of agricultural education of the manager was also included as an explanatory variable (*manag edu*) in the model. The categories for the categorical variable "management education level" are as follows: 1) none; 2) vocational training; 3) skilled worker; 4) plant engineer; and 5) agriculture engineer. Finally, εi is the model's error term.

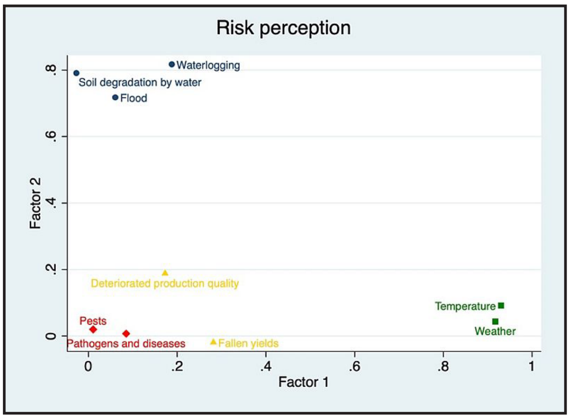
In addition, the odds ratio was calculated to offer a precise measure of the constant impact risk perception has on the likelihood of adopting or not adopting an innovative strategy to reduce climate change consequences.

Results and discussion

The study was conducted in two different steps: the first one consisted of a factorial analysts aimed at identifying the main impacts, resulting from climate change, on agricultural productivity. Subsequently a logit model was impended to assess the probability of farmers adopting strategies to mitigate climate change damage.

According to main findings derived from the Explanatory factor analysis (EFA) it emerges the existence of four latent variables that assume different and antithetic features. These variables, according to the farmers opinions, represents the main group of potential risks deriving from the climate changes,

As shown in Table 5, variables were synthesized and named as follows: i) meteorological changing, ii) economic damage, iii) water damage and iv) insect's damage, revealing the mainly climate change effects perceived by Hungarian farmers (Figure 1).



Source: authors'eleboration

Figure 1: EFA plot on farmers' risk perception.

The first factor, defined as meteorological changes construct, concerns the perception of increasing temperature and decreasing rain while water damage means perception of floods caused by meteorological events.

The insects damage and economic damage indicate the pests and diseases damages affecting crops, and a decrease in crop quality and yield due to climate change respectively. The factor loading of each item is shown in Table 5 ranging from 0.72 to 0.93.

As reported in Table 6, the findings reveal that all climate change effects (meteorological changing, economic damage, water damage and insect's damage) influence positively the probability of Hungarian agricultural farms to use agro-meteorological data to improve their agronomic and economic performances.

Meteorological events caused by temperature (2.13***) and the presence of pests, pathogens, and diseases (2.01***) are particularly strongly and positively correlated with the likelihood that

Variables	Item	Meteorological changing	Water damage	Insects damage	Economic damage
k1	The weather became volatile	0.92			
k2	The average temperature has risen	0.93			
k5	The quality of my produce has deteriorated				0.82
k6	Yields have fallen				0.81
k9b	Soil degradation water		0.79		
k9d	Waterlogging		0.82		
k9e	Flood		0.72		
k9h	Emergence of new pests			0.93	
k9i	Emergence of new pathogens and diseases			0.92	

Note: * varimax blank 0.6.
Source: authors'eleboration

Table 5: Exploratory factor analysis (EFA) results.

agricultural operators will use agro-meteorological data as an innovation tool to forecast events and thus attempt to avoid damage caused by climate change.

The perception of water damage (1.83**) is also positively correlated with the likelihood of utilizing forecasting data, whereas the perception of a decline in production quality and yield (-0.66*) as an economic risk appears to be negatively correlated with the likelihood of utilizing agro-meteorological data. Additionally, the manager's education is strongly connected (1.78**) with the possibility of using agrometeorological data.

	Coeff.	*Odds ratio*
Economic damage	-0.415	-0.66**
Meteorological changing	0.757	2.13***
Water damage	0.607	1.83**
Insects damage	0.696	2.01***
Manager's education	0.578	1.78**

Note: ***, ** Indicate significance at 0.01 and 0.05 levels, respectively.
Source: authors'eleboration

Table 6: Logit results on agrometeorological data.

Results in Table 7 showed the that the probability of a farm to adopt new warm and floods resistant crop varieties is positively associated to the perception of meteorological change (1.66**), water damage (1.63*), and insects damage (2.91***). Conversely, the probability to cultivate new crop varieties seems not affected by the perception of economic loss due to climate change. Additionally, the manager's education positively affects (1.81**) the possibility of using new varieties.

	Coeff.	*Odds ratio*
Economic damage	0.096	1.10
Meteorological changing	0.505	1.66**
Water damage	0.489	1.63*
Insects damage	1.070	2.91***
Manager's education	0.595	1.81**

Note: ***, **, * Indicate significance at 0.01, 0.05, and 0.10 levels, respectively.
Source: authors'eleboration

Table 7: Logit results on the use of new warm and floods resistant crop varieties.

As for the adoption of ice and frost protection improvements as innovative strategy to reduce negative effects of climate change, Table 8 indicate that the perception of economic damage (1.62***), water damage (2.18***), as well as insects damage (1.62***) increase the probability of Hungarian farmers to use novel techniques for minimizing cold and frost damages. Moreover, none statistically significant effect has the perception of changing of temperature and precipitation as well as the manager's education level in adopting innovative technologies for ice and frost protection.

	Coeff.	*Odds ratio*
Economic damage	0.483	1.62**
Meteorological changing	-0.042	0.96
Water damage	0.779	2.18***
Insects damage	0.484	1.62**
Manager's education	0.169	1.18

Note: ***, ** Indicate significance at 0.01 and 0.05 levels, respectively.
Source: authors'eleboration

Table 8: Logit results on ice and frost protection improvements.

Discussion

The study revealed interesting results can assist clarify how perceptions of climate change-related dangers impact Hungarian farmers' adoption of mitigation techniques.

Previous studies have already discussed how experiences related to natural disasters have had indirect impacts on economic and technological strategies through the application of innovations by farmers (Li et al., 2021).

This section provides a briefs discussion by responding to five research questions.

RQ1. Concerning the first research question, the findings of the factor analysis indicate that the main factors perceived by Hungarian farmers as compromising the agricultural productivity are damages related to temperature volatility (Ricart et al., 2022), and in particular the increase in average temperature. In addition, farmers believe that important damages are also related to flooding resulting in soil erosion (Oh et al., 2023; Angra et al., 2022); as well as to the damages resulting from new pathogens and diseases; that cause economic damages related to a reduction of the quality and yield of crops (Datta et al., 2022).

RQ2. Related to the second research question, the key finding is that the perception of temperature and precipitation changing, water and insect damage increase the probability that farmers use agrometeorological data (Guo et al., 2023). A possible explanation of this outcome is that the perception of a damage due to insects, or caused by a flood, prompts the farmer to use agrometeorological data to carry out effective insect treatments, or to prevent flooding or drought conditions by implementing ad hoc interventions. This result is confirmed by scientific studies where the use of agrometeorological data is helpful to assist irrigation management (Culman et al., 2019) as well as the control of pests and diseases (Orlandini et al., 2020). Conversely, our findings revealed that the use of agrometeorological data decreases as the economic damage increases and consequently the probability to adopt this kind of innovation is lower. It also makes sense since several scientific papers pointed out that the access to sets of weather data could be quite expensive (Chirico and Bonavolontà, 2020).

RQ3. As regards the third research question, our results confirm that utilizing new warm and floods resistant crop varieties is a fresh challenge for adopting new production techniques in response to changing climatic conditions. Consequently, the possibility of adopting new varieties is favorably impacted by the farmer's impression of changing temperature and precipitation, as well as the farmer's assessment of water and insect damage (Raza and Bebber, 2022). These results are coherent with previous literature whereby the farmer's perception of increasing temperature as well as the risk of waterlogging and the consequent dissemination of pests and diseases could push farmer to adopt crop varieties more resistant to drought, waterlogging or to such insects and diseases (Juroszek et al., 2022). In this direction, a recent study of Harsányi et al. (2021) underlines the introduction of new varieties of sunflower resilient to drought as an important strategy to overcome the yield loss in Hungary. Moreover, the outcomes of our research are in line with Aristya et al. (2021), who have highlighted how the introduction of new crop varieties resistant to pests and diseases helps to increase crop yield.

RQ4. Pertaining to the fourth study question, the study findings revealed the positive effect of perceived economic damage, perceived water damage and the perceived insects damage on the farmer's probability to adopt innovative techniques for ice and frost protection. This result is quite in line with a previous study (Wisniewski et al., 2008) that has previously emphasized the significance of frost protection by inhibiting the ice propagation from outside to inside plants. Consequently, the widespread perception is that the economic damage, water damage and damage caused by insects could prompt farmers to protect their crops from ice and frost, maybe because freezing reduces the vigour of plants thus exposing them to pests and diseases attacks (Chahal et al., 2022; Hamam et al., 2022b). Accordingly, protecting plants from ice and frost could be seen an effective tool for reducing yield loss and economic damage.

RQ5. Regarding the fifth study question, our findings show that the education level of farmers seems to impact the probability of adopting agro-meteorological data. The positive effect of manager education variable on the probability to adopt weather forecasts data agrees with scientific literature (Nkuba et al., 2023), thus confirming that the innovation adoption in agriculture is positively related to a high level of education and know-how of farmer. In agreement with what has been said, we also found the positive effect of farmer's level of manager education on the probability to adopt new varieties for mitigating the consequences of climate change on agricultural crops.

Conclusion

Climate change is becoming the main issue for all over the world. Hungary, which is located in the central Europe, is not exempt from this problem, suffering of animal devastation, yield loss and risk of hunger caused by climate change consequences, particularly droughts and floods. However, little is known about the farmer's perception on climate change consequences on agricultural crops and on their propensity to adopt technical innovations for overcoming negative effects of climatic events.

Given the paucity of studies conducted on the perception of climate change in middle Europe, the novelty of this study is to fill this gap in the literature by analyzing the most prominently perceived negative effects of climate change in EU eastern country and how these may affect the propensity of Hungarian farmers to adopt technological innovations such as agro-meteorological data, new varieties, and ice and frost protection.

The main results showed that the adoption of the technical innovations included in this study depends on the farmer's perception of climate change consequences on agricultural crops. Moreover, the managerial capability of farmer also affects the probability to adopt agrometeorological data and new varieties.

The results of the research will be of considerable interest to stakeholders and policymakers in their efforts to increase the use of technologies to safeguard Hungarian crops against climate change. A helpful outcome of the research is enhancing farmers' understanding of the effects of climate change, for instance by holding seminars with farmers to discuss the danger of adverse effects of climate change on agriculture. Facilitating the transmission of adaptation-related knowledge and expanding farmers' social networks should inspire farmers to advocate for more effective climate change mitigation strategies. On the other side, our findings show that policymakers could provide farmers with economic incentives to encourage the adoption of innovations, such as the utilization of agrometeorological data. Increasing the farmer's administrative capacity to implement technological innovation is also required. In this regard the EU, in the 2021-2027 multiannual financial framework, is investing significant amounts of its budget in climate-related expenditures. All climate adaptation actions are to be integrated into all major EU spending programs, and to this end a monitoring system has been established to ensure that these goals are met. It is assumed, therefore, that these investments will support the appropriate instruments to mitigate climate change.

Nevertheless, this research is not exempt from some limitations. The main of them can be attributed to the use of a convenience sample of farmers, besides being referred to a particular EU eastern country. Another constraint of this paper relies on the limited number of innovative climate change adaptation tools. Consequently, this study gives way to incremental research based on a representative and cross-national sample. However, comparable research might be undertaken in the next future in other European nations to observe different perspectives of farmers of neighboring countries about climate change. Additionally, it would be useful to investigate other variables or obstacles that impact the chance of utilizing additional technical innovations to reduce the output losses due to climate changes.

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