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Adapting Agriculture: Policy Implications of the Rise of Resistant Seeds in Farmers' Climate Change Strategy

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Abstract

This paper explores farmers' perceptions of climate change and their preferred adaptive and mitigatory strategies within Slovakia's Nitra region, aiming to devise recommendations for climate change-oriented agricultural policies. Our methodology incorporates an analysis of perspectives gathered from a regional survey using the Analytical Hierarchy Process (AHP) and SuperDecisions software, complemented by a risk-attitude assessment using the modified Multiple Price Lists (MPL) method. A subsequent heterogeneity analysis correlates these preferences with respondents' socio-economic status and risk attitudes. Our findings underscore the use of improved, resilient seeds as a favored adaptation measure and reveal a correlation between farmers' socio-economic attributes and their climate change strategy preferences. Based on this, we propose inclusive, micro-level agricultural policies that prioritize the unique climatic needs of the Nitra region and strongly consider the priority viewpoints of farmers within this region, aiming to promote sustainable agriculture under changing climatic conditions.

Keywords

Preferences, climate change, adaptation, mitigation, support policy, AHP, GMO.

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Introduction

The agricultural sector is a very distinctive area of the national economy, characterized by significant barriers to entry such as the need for substantial initial capital and seasonality, which among other things, results in irregular and sporadic income for agricultural enterprises (Mukaila, 2022). However, agriculture is increasingly associated with landscape maintenance, rural development, and environmental protection. Agricultural production impacts the improvement of the rural population's living standards and mitigates the effects of urbanization and a changing climate (Adger et al., 2009). Pretty et al. emphasizes the critical role of sustainable agriculture in improving the livelihood of rural populations and mitigating the impact of environmental changes (Pretty et al., 2018). Agricultural support is dependent on state support policies, which are subject to various internal and external influences. Therefore, agricultural policy is becoming increasingly important. For an agricultural enterprise, state support is a significant factor that affects many aspects of its operations (Brooks, 2014).

Another crucial factor exerting a considerable impact on agriculture is climate change. More intense rainfall and higher temperatures are projected for Europe due to climate change (Berg et al., 2013). Changes in temperature and precipitation, as well as weather and climate extremes in Europe, are already influencing crop yields and livestock productivity (EEA Report, 2019; Scherrer et al., 2016). Weather and climate conditions also affect the availability of water needed for irrigation, livestock watering, processing agricultural products, and transportation and storage conditions. Climate change can also cause significant shifts in what and where European farmers can produce (Nelson et al., 2014). The extent of climate change impacts will depend on various factors such as geographic area, socio-economic development, changes in agroecosystems, and the adaptability of a given region (Ciscar et al., 2018; Raza et al., 2019). Agriculture itself also has a significant environmental impact, particularly through the release of greenhouse gases and pollutants that contaminate the air and soil (Lynch, 2021). Climate change directly and indirectly affects agricultural production and the agroecosystems upon which farmers rely.

In the future, these already observed impacts of climate change are expected to deepen (Peltonen - Sainio et al., 2011).

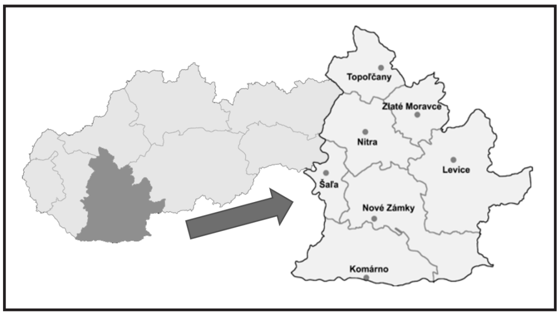
Agriculture thus influences the landscape not only as an area that ensures food production but also values that are not subject to production and trade, such as biodiversity, cultural and aesthetic value of the landscape, and a quality of environment. The role of the state is to ensure and support agriculture so that its sole objective is not just the production of sufficient quantities of quality food for the population but also to maintain the landscape, develop rural areas, and the currently much-needed environmental protection. Therefore, future measures in agriculture should focus on those that bring comprehensive benefits in terms of economy, food security, adaptation and mitigation of the impacts of climate change, biodiversity support, and environmental protection. As per the findings of Torres et al. (2020), future agricultural policies addressing climate change need to align with farmers' preferences and behaviors, be inclusive, and consider farm and farmer typologies at the micro-level.

In this context, the objective of our research was to determine the relative importance of various climate change adaptation and mitigation actions connected to agricultural activities in a Nitra region in Slovakia. This information is intended to help policymakers focus on prioritized solutions that enhance the sustainability of agricultural systems (Firley, 2023). Additionally, we analyzed the relationship between farmers' preference structures, their risk attitudes, and their socioeconomic characteristics and propose inclusive agricultural policies that prioritize the unique climatic needs of the Nitra region and strongly consider the priority viewpoints of farmers.

Materials and methods

Given the objective of the study, we decided to divide our research into multiple sections. We conducted a thorough analysis of the study region from both a climatic and agricultural perspective, highlighting the development of climate change and agricultural aspects within Nitra region. Through a comprehensive review of relevant literature and an analysis of the region's climatic and agricultural features, we were also able to identify appropriate adaptive and mitigating measures. We also focused on an analysis of farmers' socio-economic characteristic and preferences for possible implementation of adaptation and mitigation measures aimed at climate change. We conducted an analysis of heterogeneity, linking farmers' preferences for measures against climate change to their expressed risk attitudes related to their farming activities and socio-economic characteristics. In the final stage, we formulated recommendations in the area of support agricultural policy under the conditions of climate change that take into account our research findings.

Data for our research was collected mainly through a survey representing a sample of 47 farmers from the Nitra region (Figure 1).



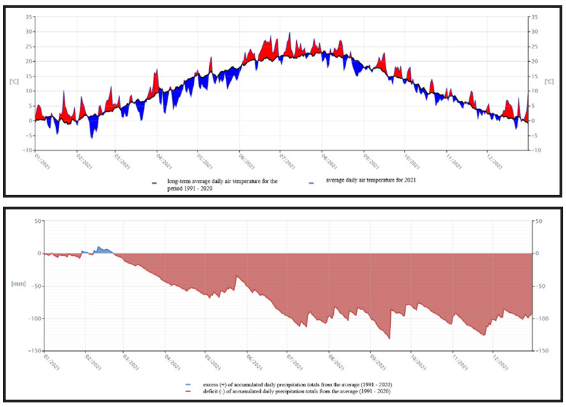
Source: Own processing

Figure 1: Study area location.

Respondents were approached based on a list and contacts of more than 120 agricultural entities provided by the Agricultural Paying Agency of Slovakia, which is a budgetary organization involved in financial relations with the budget of the Ministry of Agriculture and Rural Development of the Slovak Republic. Data collection took place in a structured format, adapted to the specifics of the surveyed subjects. Farmers filled out the questionnaire from December 2022 to April 2023. In case of ambiguities and additional questions from respondents about the survey questions, a structured interview was conducted with the respective respondent to obtain the requested information. The questionnaire contained 25 questions and was divided into 4 blocks according to the types of information collected. The survey was divided into the following sections: 1) Characteristics of the farmer and the farm (respondent's persona, legal entity - type of the farm, production); 2) Socio-economic status of farmers (land, education and investments, insurance, subsidies); 3) Environmental attitudes and opinions of farmers, and their preferences for climate change adaptation and mitigation measures. 4) Farmers' attitude towards risk. Each farmer needed approximately 50 minutes to answer the questions, and the survey was conducted in accordance with confidentiality rules and principles of personal data protection for each participant. Moreover, each participant was informed about the survey's purpose.

The Nitra region is one of the eight autonomous regions of Slovakia. With its area of 6,343.7 km^2, the Nitra region occupies 12.9% of the territory of the Slovak Republic. According to the Statistical Office of the Slovak Republic, the region manages the largest area of agricultural land among all the regions of Slovakia. The total land fund of the region is 643,318 hectares. Of this, agricultural land comprises 469 thousand hectares, representing 74% of the total area of the region in terms of percentage evaluation (Statistics Office of the Slovak Republic, 2021). This region has long been one of the most significant agricultural producers. The most common are crops such as wheat, barley, corn for grain, edible peas, technical sugar beet, oilseed rape, sunflower for seed, and it is the largest producer of cereals, oilseeds, legumes for grain and grapes in Slovakia. In the Nitra region, compared to other regions, plant production is dominant. Némethová and Feszterová (2019) study found that crop production was more profitable than animal production in Nitra region, especially in the case of cereals and oilseeds. There are also cultural and historical reasons for the emphasis on plant production (Izakovičová et al., 2022).

Data show temperature and rainfall changes over the past few decades (Figure 2).



Source: Slovak Hydrometeorological Institute, 2021

Figure 2: Average daily temperature (◦C) and excess and deficit of accumulated amount of Average daily temperature (◦C) and excess and deficit of accumulated amount of precipitation (mm) (2021) amount of precipitation (mm).

This is suggested by meteorological data for the last 30 years (1991-2021), which show an upward trend in the average annual temperature and a downward trend in the annual average amount of precipitation (mm). The NUTS3 region, which includes Nitra, recorded an average annual temperature increase of +2.72 °C between the 60s and the period 2009-2018. This places it first among the NUTS3 regions in Slovakia where the temperature has risen the most.

The Analytical Hierarchy Process (AHP) was used to identify farmers' preferences and estimate the relative importance (i.e. priorities) of various adaptation and mitigation measures. The AHP method is a multi-criteria analytical tool developed by Saaty (2001) in the late 1970s. It is frequently utilized in agricultural research, particularly in analyzing farmers' attitudes and setting priorities in their decision-making, resolving agricultural and environmental problems, and analyzing marketing issues related to consumer preferences (Kallas and Gil, 2012, Ndamani and Watanabe, 2017, Aslam et al., 2018). The AHP method includes 3 main phases: 1. modelling, 2. evaluation, and 3. priority setting and synthesis.

Phase 1. Modelling - In this phase, we carried out activities: a) identification and definition of the problem and b) structuring the decision-making model in the form of a hierarchy.

Ad a. Identification and Definition of the Problem - From the study of the given issue, we found that currently there is a lack of information and data indicating the preferences of farmers in Slovakia regarding adaptation and mitigation measures in the area of climate change, as a normative framework for creating public policies related to agricultural production under climate change conditions. Globally, farmers are incorporating a range of strategies that include, but are not limited to, improved crop and livestock management practices, increased use of drought-resistant crop varieties, precision farming techniques, agroforestry, and conservation agriculture (Lal, 2015). Enhanced crop and livestock management strategies involve adjusting planting dates, altering the mix of crops and livestock species, and improving irrigation efficiency (Havlík et al., 2014). In many parts of the world, precision agriculture, which uses technology to optimize returns on inputs while preserving resources, is becoming more prevalent (Zhang et al.,2002). Another widely recognized measure is the use of drought-resistant crop varieties, which has become increasingly important as many regions experience more frequent and severe droughts (Howden et al., 2007). Conservation agriculture, including practices such as cover cropping and no-till farming, can improve soil health and water retention, reduce erosion, and sequester carbon, making it an effective mitigation and adaptation strategy (Powlson et al., 2014). Lastly, agroforestry systems can enhance resilience to climate change by improving soil quality, biodiversity, and carbon sequestration (Mbow et al. 2014).

When choosing the measures from which our survey subsequently proceeded, it was necessary to consider the constraints and specifics associated with the analyzed Nitra region. The identified measures (Figure 3), based on which the hierarchical analysis was carried out, were organized into two main groups. Measures implemented to strengthen resilience to climate change at multiple levels were defined as adaptation measures, and measures aimed at reducing greenhouse gas emissions from agriculture were defined as climate change mitigation measures (Mussetta et al., 2017). Based on a broad variety of adaptation and mitigation strategies, we chose those that, given the current scientific research, we believed to be the most appropriate for the chosen area.

A1 - Changing crop production - Some crops may adapt better to these changing conditions, requiring fewer resources (Challinor et al., 2014). Crop selection must consider factors such as soil, water, and market demand (Lobell et al., 2008). Research indicates certain crops like maize, wheat, and rice can withstand climate variations (Zhao et al., 2017).

A2 - Enhanced and resistant seeds/varieties - Embracing genetically enhanced and resistant crop varieties can significantly increase yield (Tester and Langridge, 2010). For instance, studies indicate hybrid corn seeds with advanced pest and disease resistance can drastically enhance yields (Castiglioni et al., 2008). Similarly, wheat varieties engineered for drought resistance have shown increased yields and superior grain quality (Trnka et al., 2011). The use of genetically modified (GM) corn with built-in pest resistance can not only improve yield but also reduce pesticide usage (Qaim and Zilberman, 2003).

A3 - Adapting the planting calendar - A study demonstrated that advanced sowing generally leads to better wheat, barley, and oats yields, though optimal dates can vary per crop and locale (Semenov and Stratonovitch, 2015). Therefore, strategic sowing schedules are suggested to maximize yield and offset risks associated with climate change (Challinor et al., 2014).

A4 - Investing in irrigation infrastructure- Careful investments in irrigation infrastructure can enhance environmental and agricultural outcomes. Modern irrigation technology can lower water use while boosting productivity (Fereres and Soriano, 2007). Khan et al.'s research corroborates this, highlighting increased agricultural productivity and profitability, alongside reduced soil erosion (Khan et al., 2009).

M1 - The restriction of tilling the soil - Limiting soil tillage, a practice known as reduced or no-till farming, can enhance soil structure, improve water permeability, and reduce soil erosion, contributing to better retention of soil moisture (Lal, 2004). This approach can also sequester carbon, helping to lessen greenhouse gas emissions (Montgomery, 2007). Additionally, reduced tillage can lower energy consumption, boosting agricultural efficiency (Pimentel et al., 2005).

M2 - Organic farming – Organic farming can improve soil quality, yielding better crop outputs and lower costs over time (Seufert, Ramankutty and Foley, 2012). Moreover, comparing farming systems, found organic farming had lower greenhouse gas emissions, less soil erosion, and improved soil quality compared to conventional farming, suggesting the former's superior environmental sustainability (Mondelaers et al., 2009). Organic farming's sustainable potential lies in minimizing synthetic inputs and fostering ecological processes.

M3 - Use of renewable energy - Leveraging renewable energy in agriculture, such as solar and wind, can lead to reduced energy costs, increased energy self-reliance, and diminished greenhouse gas emissions (Kumar et al., 2013). Renewable sources, along with biogas production, can considerably reduce emissions and improve energy self-sufficiency, provided supportive policies and financial mechanisms are in place (Edenhofer et al., 2013).

CLUSTER 1

Addressing climate change through adaptation and mitigation measures

Adaptation Measures	*Mitigation Measures*
- Changing crop production (A1)	- The restriction of tilling the soil (M1)
- Enhanced and resistant seeds/varieties (A2)	- Organic farming (M2)
- Adapting the planting calendar (A3)	- Use of renewable energy (M3)
- Investing in irrigation infrastructure (A4)	- Using new, less polluting, and energy-efficient machinery (M4)
CLUSTER 2	CLUSTER 3

Source: Own processing

Figure 3: Identified adaptation and mitigation measures.

M4 - Using new, less polluting, and energy-efficient machinery - Modernizing farm machinery for greater energy efficiency and reduced emissions can lead to several benefits, such as cost savings, improved air quality, and a lower carbon footprint. Ogle et al. (2005) in their study suggests that changes in agricultural management, including the use of modernized machinery, can improve energy efficiency and thereby reduce greenhouse gas emissions. Moreover, adopting precision agriculture technologies, like GPS-guided tractors and drones, can decrease fuel and fertilizer use, and greenhouse gas emissions while improving crop yields and reducing production costs, thereby enhancing farmers' profitability (Griffin et al., 2004).

Ad b. The Structure of the Decision Model in the Form of a Hierarchy - The chosen hierarchical model (Figure 3) captures the identified measures based on what is most accepted according to the preferences of farmers. In our model we had two levels. Cluster 1 (adaptation vs. mitigation) was located in the first level and cluster 2 (adaptation measures) and cluster 3 (mitigation measures) in the second level.

Phase 2 - Decision making - Respondents made decisions using pairwise comparisons of all elements at each level of the cluster (Figure 3) using Saaty's proposed scale (Scale from 1 - Both measures are equally important to 9 - The preferred measure is substantially more important than the others), based on which we later estimated the relative importance of alternative measures. For a cluster 1, only one pairwise comparison is applied [n·(n-1)/2 = 2·(2−1)/2 = 1] to adaptation and mitigation measures. For each of the clusters at the lower level according to the dimension n = 4 (4 alternative actions), 6 pairwise comparisons were used [n·(n-1)/2 = 4·(4−1)/2 = 6], where each alternative in the hierarchy was compared with the remaining alternatives within its cluster at the same level, depending on the satisfaction it provides to the respondent (farmers). Pairwise comparisons were collected in our survey.

Phase 3 - Priority setting and synthesis - This phase includes: a) synthesis to identify the best alternative and b) examination and validation of the decision, which correspond to the last two activities of the hierarchical analysis process, through which we estimated priorities (i.e. relative importance).

Ad a. Synthesis to Identify the Most Preferred Criteria - In this part of the model, joint prioritization of all sub-criteria proposed in the model was carried out to select the one that solves the given problem; up to this point, we had to make all comparisons between the elements of each cluster for each farmer (k), from which we obtained the corresponding Saaty matrices ($\hat{A}_k$), through which the local weights of the identified elements $\widehat{w}_{iK}$ were obtained according to the preferences of each farmer using the Row Geometric Mean Method (RGMM) (Kallas and Gil, 2012). The estimate of priorities $\widehat{w}_{iK}$ as realized using the Super Decisions software designed to implement the AHP methodology. All judgments ($\hat{a}_{ijk}$) obtained from pairwise comparison led to the construction of a Saaty matrix for farmer k ($\hat{A}_k$) with dimensions (n x n = 4×4). Example of a Saaty matrix:

$$\hat{A}_k = \begin{bmatrix} a_{1.1k} & a_{1.2k} & a_{1.3k} & a_{1.4k} \\ a_{2.1k} & a_{2.2k} & a_{2.3k} & a_{2.4k} \\ a_{3.1k} & a_{3.2k} & a_{3.3k} & a_{3.4k} \\ a_{4.1k} & a_{4.2k} & a_{4.3k} & a_{4.4k} \end{bmatrix}$$

Based on the Saaty matrix, we estimated the relative importance (i.e. weights or priorities) of different actions using RGMM:

$$\widehat{w}_{ik} = \sqrt[n]{\prod_{i=1}^{i=n} \hat{a}_{ijk}} \quad (1)$$

The previously estimated values are normalized to one

$$\sum_{i=1}^{j=n} \widehat{w}_{ik} = 1 \quad (2)$$

Ad b. Examination and validation of the decision

In the verification phase, it is important to note that for each generated matrix, the consistency ratio (CR) of farmers' responses was calculated according to the corresponding mathematical expressions:

$$CR = CI/RI \quad (3)$$

Where *CI* is the consistency index obtained as:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

Where n is the number of alternatives and λ_max is the maximum value of the components of the vector obtained as:

$$\lambda_{max} = \Sigma_i \Sigma_j \hat{a}_{ijk} \widehat{w}_{ik} \quad (5)$$

RI is a random index, which was obtained by multiple random extraction of the Saaty matrix of size n x n (Table 1). A CR value lower than 10% indicates satisfactory consistency for pairwise comparisons (Siraj et al., 2015).

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Own processing based on Saaty (1994)

Table 1: RI index.

The level of risk posture is related to human behaviour, which is specific to each individual with decision-making authority. Individuals prefer options that provide greater utility based on their risk preferences (Brick et al., 2012). **The MPL method** or "lotteries" is used in the agricultural sector based on the expected utility theory u(x) and risk preference strength v(x) with a "real equivalent" used to measure risk attitudes (Pennings and Garcia, 2001). The MPL method allows identification of levels of tolerance or aversion to risk through a set of questions posed to decision-making individuals - in our case, farmers. We examined 8 scenarios with different lottery pairs, where the respondent chose one option (Option A or Option B). The degree of risk aversion is based on the number of safe answers (Option A) chosen by the respondent. A respondent who is risk-tolerant chose the safe option (Option A) only for the first and second scenario. A farmer who is neutral towards risk chose option A for the first to fourth scenario and option B for the remaining scenarios (Scenarios 5 to 8). A farmer with risk aversion chose option A for scenarios 1 to 7 and a farmer with extreme risk aversion chose option A for all 8 scenarios. In the given model, the safe option (Option A) corresponds to a 100% probability of success and the risk option (Option B) corresponds to a 50% probability of achieving success and a 50% probability of failure (based on a coin toss). The value of success provided by Option A gradually decreases.

Hypotheses analyzed

H1: The estimated preferences of farmers regarding adaptive measures and climate change adaptation measures (AHP method) were influenced by declared risk attitudes (MPL lotteries).

H2: The estimated preferences of farmers regarding adaptive measures and climate change adaptation measures (AHP method) were influenced by the socio-economic characteristics of the farm.

The above hypotheses were analyzed using the Kruskal-Wallis test. Which is non-parametric test used to determine whether there are significant differences between multiple groups based on a single dependent variable (Kruskal and Wallis, 1952). To test the chosen hypotheses, we therefore performed a separate Kruskal-Wallis test for each of the eight dependent variables, comparing multiple dependent groups (8 preferences) based on respondents' declared independent variables (risk attitudes and socio-economic variables). This allowed us to determine if there were any statistically significant differences between the groups in terms of their preferences for the selected measures, and whether these differences were influenced by their declared independent variables.

The test statistic for the Kruskal-Wallis test was calculated as follows:

$$Q = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{T_i^2}{n_i} - 3(n+1) \qquad (6)$$

- n is the total sample size in all groups
- n_i is the sample size for group i
- T_i is the sum of ranks for group i

The test statistic follows a X^2-distribution with degrees of freedom equal to the number of groups minus one (k-1), where k is the number of groups being compared. The p-value was then calculated from the X^2-distribution using the degrees of freedom and the calculated test statistic. If the p-value is less than the chosen significance level (set at 0.05), we reject the null hypothesis and conclude that there is a significant difference between the groups being compared.

Results and discussion

We utilized the AHP to identify farmer preferences and estimate the relative importance (i.e., priorities) of various adaptation and mitigation measures. Weights (i.e., relative importance) were estimated at the local (i.e., for each cluster from local weights) and global level (i.e., for the level of hierarchy from global weights). Based on the measure the respondent preferred, we identified the value of the relative importance of each measure. Table 2 shows the values of relative importance of specific adaptation and mitigation measures.

Cluster 1	
Adaptive measures	0.61
Mitigation measures	0.39
Cluster 2	
Adaptive measures	Value of relative importance
Investments to improve irrigation infrastructure	0.14
Changing production	0.18
Adapting the sowing calendar	0.29
Enhanced and resistant seeds/varieties	0.4
Cluster 3	
Mitigation measures	Value of relative importance
Organic farming	0.11
Limitation of soil tillage (Zero tillage management)	0.35
Use of renewable energy	0.24
Use of less polluting and energy-efficient machinery	0.3

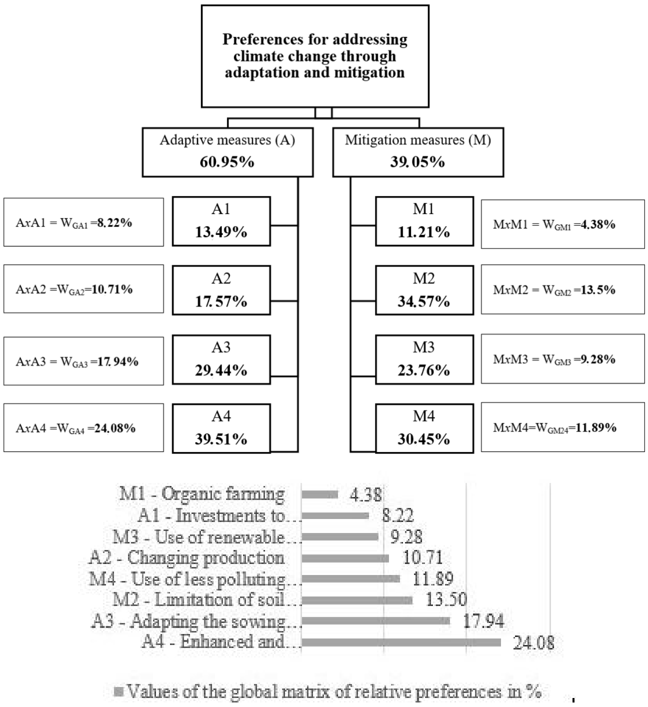
Source: Own processing

Table 2: Values of the matrix of relative importance of individual adaptation and mitigation measures AHP method.

The weights of relative importance of preferences in the matrix for adaptation measures reached a value of 0.60947, which, rounded to two decimal places, represents a preference level of 60.95%, and the preference value for mitigation measures 0.39053, which represents 39.05%. The estimated weights show that adaptation measures, as a whole, were considered more important and preferred by farmers. In the calculation of relative importance of preferences, we verified the consistency ratio within each cluster, according to the chosen methodology. The consistency value for pairwise comparisons of adaptation measures reached a value of 0.06827, which represents 6.82%. The consistency value is satisfactory, as it is less than 10%.

At the next level of our hierarchy, in cluster 2, the weights of relative importance of preferences for adaptation measures in the matrix reached the highest value for measure A4 - Use of new, improved, and resistant seeds, with a value of 0.39508, or 39.51%. The highest preference for this measure indicates that farmers see significant potential in enhancing crop resilience through genetic improvements. The second most preferred measure was A3 - Adapting the sowing calendar (29.44%). Farmers considered A2 - Changing production the third most advantageous measure among adaptation measures, this measure reached a preference value of 17.57%. The measure with the lowest preference value in cluster two was A1 - Investments to improve irrigation infrastructure (13.49%). This could suggest that farmers might perceive the cost of improving irrigation infrastructure as prohibitive, particularly for small-scale or financially constrained operations. Improvements to irrigation systems can involve significant capital expenditure, ongoing maintenance costs, and possibly higher water usage costs. The consistency value for pairwise comparisons of adaptation measures reached a value of 0.06827, which represents 6.82%. The consistency value is satisfactory as it is less than 10%.

In cluster 3, the most preferred mitigation measure was M2 - Limitation of soil tillage (Zero tillage management), with a relative preference value of 34.57%. This suggests farmers acknowledge the role of conservation agriculture in both preserving soil health and reducing carbon emissions. The use of less polluting and energy-efficient machinery – M4 being the second most preferred (30.45%) signals an interest in reducing the carbon footprint of farming operations. However, the lower preference values for the M2- use of renewable energy (23.76%) and M1- organic farming (11.21%) might indicate perceived barriers such as cost, lack of access to technology, or the need for substantial operational changes. The consistency value for pairwise comparisons of mitigation measures reached a value of 0.0975, which represents 9.75% and is also satisfactory.



Source: Own processing

Figure 4: Preferences for addressing climate change through adaptation and mitigation.

From the preference weights of adaptation and mitigation measures as a whole, we identified the value of global relative preferences for adaptation and mitigation measures based on individual farmer preferences. The use of new, improved, and resilient seeds, as a type of adaptation measure, is the most preferred measure among respondents (24.08%). Saad et al. (2022) in his research also recognizes the importance of genetic improvements for developing crops that can adapt to changing environmental conditions. The second most favored measure was the adjustment of the sowing calendar, garnering a preference of 17.94%. Limiting soil tillage, which serves as a mitigation measure, was the third most preferred strategy among our respondents with a 13.5% preference. Lal (2004), a prominent soil scientist, details how practices such as zero tillage can help sequester carbon in soils, which is an important strategy for climate change mitigation. The use of new, less polluting, and energy-efficient machines was the fourth most preferred measure in our study, aligning with a 11.89% preference. This supports findings from similar study made in Mexico from Torres et al. (2020) that suggests public policy should promote the use of less polluting and more efficient agricultural machinery because farmers preferred this measure and thus the positive results in context of climate change could be further intensified. This was followed by a change in production (10.71%), the use of renewable energy (9.28%), and investments in improving irrigation infrastructure with a global preference value of 8.22%. Organic farming was the least preferred option with a preference value of 4.38%, as shown in Figure 4.

The MPL results regarding the stated risk attitudes show that the majority of respondents have risk aversion, rounding to whole numbers, up to 53% of surveyed farmers. 36% of respondents have extreme risk aversion, 11% are neutral, and no respondent chose the risky option for the first two scenarios, so 0% of respondents are risk-tolerant.

All chosen hypotheses were tested using the Kruskal-Wallis test.

H1: Farmers' preferences for adaptation and mitigation measures are influenced by their declared risk attitudes.

The level of risk tolerance and respondent preferences regarding climate change adaptation and mitigation measures were subjected to analysis, based on which we found that risk attitudes and farmer preferences for adaptation and mitigation measures are not clearly related. The analysis performed did not reveal any significant relationship between preferences for adaptation and mitigation measures and the level of risk tolerance.

H2: Farmers' preferences for adaptation and mitigation measures are influenced by the socio-economic characteristics of the farm.

Various socio-economic characteristics and respondent preferences regarding climate change adaptation and mitigation measures were subjected to Kruskal-Wallis test analysis for the purpose of finding a correlation between individual socio-economic factors and preferences for measures. Specifically, we examined 3 factors, namely the level of agricultural education achieved, the type of legal entity, and the last examined factor was the existence of agricultural insurance.

Our analysis reveals a significant correlation between the level of education of respondents and their preferences for adaptation and mitigation measures in farming. Further, we discovered a significant relationship between the type of legal entity and farmers' preferences for adaptation and mitigation measures. Contrastingly, the analysis did not indicate a significant correlation between a farm's insurance status and preferences for adaptive and mitigation measures.

The finding that the most preferred adaptation measure among farmers is the use of new, improved, and resilient seeds is also in line with the results of other studies, which also found that crop breeding and genetic improvements are considered by relevant parties to be key strategies for adapting to climate change in agriculture. Mohd Saad et al. (2022) emphasizes the need for future crop improvement efforts to rely on integrated genomic strategies. They highlight the need to develop future crops that are highly resilient and adaptable to changing environments for maintaining global food security. Pourkheirandish et al. (2020) discusses the importance of development of climate change resilient crops, how advancements in genomics can transform plant breeding, and how such technology can help overcome the challenges posed by climate change.

In Europe's agricultural sector, the role of Genetically Modified Organisms (GMOs) remains a contentious issue, yet one that cannot be dismissed in light of the growing demand for climate-resilient farming practices. As highlighted by our study, the utilization of new, improved, and resilient seed varieties has been marked as a preferential adaptation strategy by farmers. Such approaches often involve genetically enhanced crops designed to resist drought, pests, and other environmental stressors, which are anticipated to increase under climate change scenarios. GMOs in this context may present a strategic tool to tackle these challenges and contribute to sustainable agriculture. The Nitra region, located in the southwestern part of Slovakia, is characterized by its fertile soil and a variety of crops such as wheat, barley, and sunflower, along with maize. Given the projected impacts of climate change, such as increased temperatures, altered precipitation patterns, and potentially more frequent extreme weather events, certain GMO crops might be beneficial for the region. Genetically modified (GM) crop that could potentially be suitable is GM maize. Maize is an essential crop for the region, and drought-resistant varieties of this crop could be advantageous in the face of climate change. According to the European Commission (2010), and others (Kvakkestad et al. 2003). Wheat is a staple crop in the Nitra region, and drought-tolerant GM wheat could potentially offer a useful adaptation strategy. Transgenic wheat varieties are being developed with enhanced tolerance to drought (Begcy and Dresselhaus, 2019). Given that water scarcity may become a critical issue due to climate change, such innovations could prove beneficial. Another important crop in the Nitra region is sunflower. GM sunflower varieties are being studied and developed, some with increased resistance to pests, others with enhanced drought resistance (Kiani, 2007). However, it is important to remember that the use of GMO crops must align with the strict regulatory guidelines imposed by the European Union and introducing GMOs into the environment also comes with potential environmental implications, such as impacts on biodiversity, are a primary concern (Hilbeck et al., 2015). Furthermore, socioeconomic implications such as potential inequality among farmers, with smaller farmers disadvantaged due to the high costs of GM seeds, is another significant issue (Stone and Glover, 2017).

Therefore, any introduction of GMOs in Slovakia - and European agriculture in general - should be carefully considered. Not only should the potential benefits regarding resilience to climate change be examined, but also the potential environmental, health, and socio-economic impacts.

We emphasize the importance of understanding the specific needs and constraints of farmers and adapting policies and interventions to meet these needs. Preference results may reflect insufficient awareness or understanding among farmers of the benefits of certain measures (e.g., irrigation infrastructure and organic farming) or the perception that their implementation is more challenging or costly than other measures.

The positive outcomes of our analysis suggest a connection between the level of agricultural education achieved and respondents' preferences for various adaptation and mitigation measures. This correlation could be due to the fact that individuals with a higher level of agricultural education may better understand the range of available adaptation and mitigation measures, along with their potential benefits and drawbacks. A respondent with a higher level of agricultural education is more likely to understand the potential benefits of selected measures and other sustainable farming practices, and therefore, is more likely to support measures that promote these practices. Another factor examined was the type of legal entity. This can be because the type of legal entity can be associated with differences in decision-making processes, priorities, and the availability of resources among different agricultural actors.

Over the years, the Common Agricultural Policy (CAP) has increasingly focused on environmental and climate protection. The new CAP for 2023 - 2027 sets adaptation in the agricultural sector as one of the main goals. Adapting to climate change has been elevated to a goal that needs to be addressed through strategic plans that member states had to develop. Slovakia's Strategic Plan for implementing the CAP for the period 2023-2027 also includes specific measures to support adaptation and mitigation in response to climate change. The plan recognizes the importance of climate change and its impacts on the agricultural sector and outlines specific measures to address this issue, such as: (1) Promoting the use of climate-friendly agricultural practices, such as conservation tillage and agroforestry, to improve soil health, water management, and biodiversity. (2) Supporting the development and use of precision farming technologies to reduce inputs and increase efficiency. (3) Supporting the implementation of agri-environmental measures that promote the protection and improvement of ecosystems and biodiversity. (4) Providing financial support for investments in agricultural enterprise infrastructure and equipment that enhance the resilience of agricultural systems to climate change, such as water management systems and renewable energy technologies. (5) Supporting the development of local food systems, which can help reduce the carbon footprint of food production and distribution by reducing the need for long-distance transportation.

In our recommendations, we focused on the most preferred measure and also took into account the results of our analysis, which indicate the existence of a correlation between the socio-economic characteristics of the respondent/farm and the degree of preference for adaptation and mitigation measures. Given these findings, we believe it is necessary to consider these specifics when selecting an appropriate policy measure and to influence the level of education and information of farmers. Equally important is considering the type of legal entity of the recipient. It is crucial to note that our survey, focusing on farmers in the Nitra region, was not representative of the entire Nitra region due to the sample size of respondents included in the study. Therefore, we must be aware of potential biases when interpreting the results. Nonetheless, the findings are valuable and useful for policymakers. As part of the AHP verification phase, we found it essential to test the consistency ratio of respondents' answers, and we subsequently included only those respondents in our study whose answers were satisfactory. Despite the results of the study not being generalizable to a larger population, they still hold significant informative value for the subjects included in the study.

Policymakers can incentivize climate-resilient seeds usage via subsidies, tax reliefs, or grants. However, alternative measures like education may be considered alongside to mitigate potential market distortions or disincentives for innovation. Arslan et al. warn that subsidies can lead to inefficiencies and can disincentivize innovation. In their study, they highlight the role of education in ensuring that subsidies lead to sustainable and efficient outcomes (Arslan et al., 2014). Offering education and training programs to farmers promotes the adoption of improved seed varieties is crucial. Workshops, conferences, and accessible resources enhance understanding and knowledge on seed selection, planting, crop management, and storage techniques, reducing post-harvest losses (Kibwika et. al., 2009). Educational initiatives can empower farmers with knowledge on sustainable practices, but financial incentives may be necessary to incite change (Prokopy et al., 2008).

The educational program should focus on seed education and be coupled with financial incentives. Success is context-dependent and ensuring wide access can be challenging. Technology, community collaborations, and direct farmer engagement can help extend education resources to remote areas. We advise focusing on education about resilient seeds, planting techniques, and crop management. We suggest implementing this measure alongside financial incentives, ensuring broad farmer access. Success depends on multiple factors, including context and current circumstances. The use of technologies like online courses, mobile apps, and video conferences can extend education resources to remote farmers. Collaborating with local communities in developing training programs ensures contextual relevance. We endorse a multifaceted approach involving technology, community programs, and direct farmer cooperation, to facilitate education and training access under diverse conditions.

Investing in research and development to create new seed varieties is also recommended. The development and use of these seeds should be accompanied by relevant regulations and safety assessments to minimize potential risks and ensure they promote fair and sustainable development. We recommend regionally-focused research to identify and create the most suitable seeds for specific climatic conditions.

Therefore, as a whole, the policy maker should prioritize policies and programs that encourage the adoption of climate-smart agricultural practices, while also providing farmers with informational support and financial protection against risks associated with climate change and the uncertainty of implementing a new measure.

Conclusion

This study advances the existing body of knowledge, offering crucial insights for policymakers who are seeking to refine support mechanisms for agricultural production in ways that align more closely with the needs and preferences of farmers. This alignment could potentially amplify the efficacy of such policies in promoting general welfare. Furthermore, it may guide public support towards prioritizing initiatives that foster the growth of more sustainable agricultural practices, both at the regional and national levels.

To combat the effects of climate change on agriculture, it's vital to implement mitigation and adaptation measures that resonate with farmers' interests and preferences. We focused on Nitra Region, one of the most productive agricultural areas, as our study region. Our findings show that the use of new, improved, and resistant seeds as an adaptation measure is the most preferred among respondents. Generally, farmers tend to favor adaptation measures over mitigation measures, as the benefits of the former are perceived to be more immediate.

Analysis of our hypotheses showed no significant relationship between risk attitudes and preferences for adaptation and mitigation measures, leading to the rejection of hypothesis H1. Our findings are in line with those of Jianjun et al. (2015), who used MPL and also found an unclear relation between risk attitudes and preferences for climate change adaptation and mitigation. Individuals who are averse to risk are usually inclined towards taking actions that prevent or protect against possible damages (Weber et al., 2002). Our study revealed that the majority of farmers in the region under investigation display a significant aversion to risk. This suggests a heightened readiness on their part to implement actions geared towards diminishing the impact of climate change, whether through adaptation or mitigation strategies. However, further analysis clearly showed that preferences were related to other socio-economic variables, specifically, the level of agricultural education of the respondent and the type of legal entity of the agricultural enterprise. There's a substantial body of research suggesting similar results that socio-economic factors, including level of education and type of agricultural enterprise, can significantly influence farmers' adaptation and mitigation strategies in response to climate change. Arbuckle et al. (2015) found that farmers with higher levels of education were more likely to acknowledge and respond to climate change, and were more willing to implement both adaptation and mitigation measures. Research also explores how different types of farming enterprises have different vulnerabilities and hence responses to climate change, based on their available resources, institutional frameworks, and social networks (O'Brien et al., 2007). Niles et al. (2013) also suggest that farmers' characteristics including their level of education and the type of their farm can influence their perception of climate policy risks and consequently their response in terms of adaptation and mitigation measures.

In conclusion, our research emphasizes the importance of understanding and addressing the preferences and needs of farmers in policy development. The success of climate change adaptation and mitigation in the agricultural sector heavily relies on well-established, flexible policies that are grounded in quality scientific research, consider various economic, social, and environmental factors, and are adapted to specific regional needs and circumstances.

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