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FARMERS' AWARENESS CONCERNING THE INFLUENCE AND MANAGEMENT OF CLIMATIC CHANGES ON ENVIRONMENTAL ECONOMY AND CROPS NUTRITIONAL STATUS

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Abstract

In our days, climate changes are globally recognized as one of the most challenging pressures on agriculture. They may have consequences not only on crop yields, but on the whole agrifood sector. A survey was conducted on 383 subjects, which own farms and confront with possible extreme phenomana as consequences of climatic changes. The questionnaires were distributed in rural areas of Bistrița-Năsăud County in autumn and early winter of 2024. The aim of our scientific approach was to identify the farmers'perceptions on the existence of climatic changes, and their particular effects on agriculture sector. The raw data were statistically processed using basic statistics and multivariate analyzis. Simple Spearman correlation between variables were established, and factorial analyzis through its component PCA (Principal Components Analysis) was implemented for emphasizing the main factors affecting the farmers awareness on climatic changes and their effects with which they may confront. The results of our study show that only part of the questioned farmers are fully aware of the presence of climatic changes, and of their effects on soil nutritional status, water availability, or productivity. This suggests the importance of implementing training programs targeted to support farmers to improve their knowledges in the field.

Key words**:** *farmer, item, questionnaire, soil, water.*

INTRODUCTION

Beginning with last two decades of the former century, climate changes have beign a constant preoccupation for people working in different economy sectors, including those invlved in environmental economy [4, 25]. Effective management of these changes requires a strategic approach that integrates both adaptive and proactive measures [8, 18, 24].

Farmers' awareness of how climate change impacts crop nutritional status bridges the gap between environmental sustainability and agricultural economic resilience, fostering adaptive practices that enhance both ecological health and food security. A key point in successful fight against consequences of climate change in agriculture is the adaptation of decision-making process to specific requirements, incorporating climate management strategies that address regional variations and local challenges [1, 3, 7, 8, 11, 15, 25, 26]. The quality and quantity of crops, which are the bascic raw materials for food and fodder is the result of contribution of several complex factors, from plant genotype, soil type and its nutritional status, cultivation technlology, to, which are added environmental factos, as sun radiation, temperature, air humidity, dew point, nebulosity, or wind velocity and direction also contribute. Those are the premises that represent continous preoccupations for farmers, also considering the necessity for adaptation to climate changes realities [11, 20, 24].

Overall, crop yields have increased worldwide in the last decades. Thus, for exemplification between 1980 and 2023, cereal yield doubled worldwide, increasing from 932.9 kg/ha in 1980, up to 1,914.5 kg/ha (with 1,137.5 t/ha in

average), with different evolutions by continents, as follows: 928.8 kg/ha (1980) – 1,914.2 kg/ha (2023) in Africa, 848.6 kg/ha (1980) – 881.1 kg/ha (2023) in Americas, 564.4 kg/ha (1980) – 2,009.3 kg/ha (2023) in Asia, 2,587 kg/ha (1980) – 1,904.6 kg/ha (2023) in Europe, 2,434.1 kg/ha (1980) – 5803.3 kg/ha (2023) in Oceania [32]. The reason for spectacular yield increases in some regions like Oceania, or Asia, and low increase as in Americas, or even decreases as in Europe, is the result of different factors. Among them we can mention technological evolutions, different agricultural policies, and not least climate changes. Thus, even though the crops yield has increased considerably worldwide, climate changes affecting this important economic index are a reality.

The average temperature increases of only 1.3°C from 1981 up to 2023 [13], have real consequences on accentuation of climatic changes translated into effects on agriculture (Table 1).

Table 1.The economic aspects of climatic changes worldwide

Parameter	Reference year, 1981	Reference year, 2023	References
Average annual temperature increase (°C)	0.437	1.737	[13]
Total yields	Stable	Fluctuating	[13], [14], [32]
Average yields	Stable	Fluctuating	[13], [14], [32]
Uncover of production costs	Casual	Frequent	[17]
Production looses	Casual	Significant	[13], [14], [31]
Financial looses	Very low	Significant	[14], [10], [31]

Source: Own synthesis based on the studied literature.

A study performed by FAO (2023) concerning the loss and damages produced at global level by climate change, emphasizes that agriculture is severely impacted with almost 39% crop losses and/or specific infrastructure [13]. Another FAO report (2021) show for the case of a country of South America, where FAO statistics emphasizes very low increase of cereal yields in the last 40 years, Uruguay respectively, increasing tendency of losses in cereal production, from 1980 to 2014, from less than 0.1 tonnes within the time interval 1980 - 1984, up to 1 tonne within 2010 – 2014, with maximum losses per 2000 – 2004 period of almost 3 tonnes for rice, and about 1.3 tonnes for maize [14].

All European Union countries are affected to different extent by clime evolution. In particular case of Romania, the effects of climate change are mainly manifested through the occurrence of drought and floods, which make Romanian agriculture vulnerable [16].

According to a feasibility study carried out in Romania (2021), the agricultural areas affected by extreme phenomena as result of climate changes decrease from 1,752,506 ha in 2015 to 171,720 ha in 2019. According to Vânătoru et al. (2013), crop losses due to drought, are observed for winter wheat, maize, and sunflower [31]. Thus, from 2004 up to 2012, maize crop losses are reported, with a maximum of over 75% in 2007, while in the same time interval for sunflower, the losses the highest share of 50.3% also corresponds to the year 2007. The same study shows that winter wheat crop was less affected by drought, losses being lower in this case, with a maximum production decrease of 44.5% observed, the same in 2007.

Frequent uncovering production costs are reported because of climate change effects upon agricultural systems [17]. Diffenbaugh et al. (2021) studied the financial impacts of climate changes expressed as global warming on crop production in the USA [10]. In terms of financial impacts expressed by crops national insurance sector, they show that global warming caused to crop insurances system losses in amount of 27 billion (19%), for a 27 years period, between 1991 – 2017. In ”least developed” and ”low-middle-income” countries drought costs the agricultural sector about 37 billion $ (of which, in African continent causing about 14 billion $), while floods about 21 billion $ from 2008 to 2018 [14]. In South Romania, variable financial losses are reported due to climate changes expressed by drought installation, from 2006 up to 2012. Expressed

in Romanian currency, the losses are within specific intervals, function of culture type, as follows: 474.3 RON (2004) – 1,522.5 RON (2012) for winter wheat; 1,011.5 RON (2004) – 2,502.5 RON (2012) for winter maize, and 428.4 RON (2004) – 1,492.2 RON (2012) for sunflower [31].

In recent years, much effort has been made by researchers to improve agricultural technologies to reduce the effects of climate change, including through precision agriculture practices [6, 8, 19, 21, 25]. An essential issue for obtaining crops of high quality and promoting modern farm managerial approaches is the correct perception of the challenges represented by a climate in continuous change [9, 22, 23, 28].

A very useful approach for understanding farmers' degree of knowledge and their atitude against climatic changes and their implications in farm management is the use of surveys. If appropriately conceived they can emphasize the key points of interest, but also misconceptions, and/or gaps in farmers' knowledge [2, 5, 18, 27].

The aim of our study is to inquire into farmers' perceptions about their current knowledge about major issues connected with climate changes effects on agriculture, as water access, soil nutrients, or growth cycle of plants.

MATERIALS AND METHODS

A survey was conducted during September – December 2024 in rural area of Bistrița-Năsăud County, on farmers actively engaged in crop production. 383 farmers were surveyed to assess their awareness and perceptions of the influence of climate change on crop nutritional status, water availability, soil health, and agricultural productivity. The Cochran formula [29] was used to establish the sample size. The rural population of Bistrița-Năsăud County was considered as 180,568 inhabitants [30].

The questionnaire was developed to address key themes concerning the managerial approach of climate changes. It concerns water availability (farmers' perceptions of how climate change affects water resources), soil health and nutrient composition (farmers' understanding of climate change impacts on soil erosion, nutrient depletion, and heavy metal accumulation), agricultural productivity (farmers' views on the primary causes of declining productivity), and plant growth and growing seasons (farmers' perceptions of how increased temperatures and shifting climatic conditions influence plant growth cycles and the length of the growing season).

Informed consent was obtained from all participants before administering the questionnaire. Farmers were assured of the confidentiality of their responses and their right to withdraw from the study at any time.

The data were analysed using both descriptive and inferential statistical methods. Spearman's correlation coefficients were computed to explore relationships between variables. Principal Component Analysis (PCA) was conducted.

Five principal components explain a significant portion of the variance in the dataset. The loadings of each variable on the principal components were analysed.

RESULTS AND DISCUSSIONS

Our survey shows that 48.04% of respondents (184 farmers) believe that climate change reduces the available one, which is the dominant and correct perception (Fig. 1). This aligns with scientific findings that highlight how rising temperatures and shifting precipitation patterns contribute to increased water scarcity in many agricultural regions. Research shows that there is a need to improve the assessment of climate change impacts by using updated strategies, like hydrological simulation models [12].

A significant portion of farmers (28.20%, 108 respondents) believe that climate change has no effect on water availability, suggesting that some may not yet perceive or experience significant changes in their local water conditions.

Meanwhile, 20.63% (79 respondents) think that climate change might increase water access, possibly due to changes in rainfall patterns in specific areas.

Lastly, a small fraction (3.13%, 12 respondents) associate climate change with an increased risk of flooding, reflecting concerns about extreme weather events.
Given that the correct response is 48.04% (reduction in water resources), the findings emphasize the pressing challenge of water scarcity in agriculture due to climate change. This highlights the need for adaptive water management strategies and sustainable agricultural practices to mitigate risks and ensure long-term food security (Fig. 1).

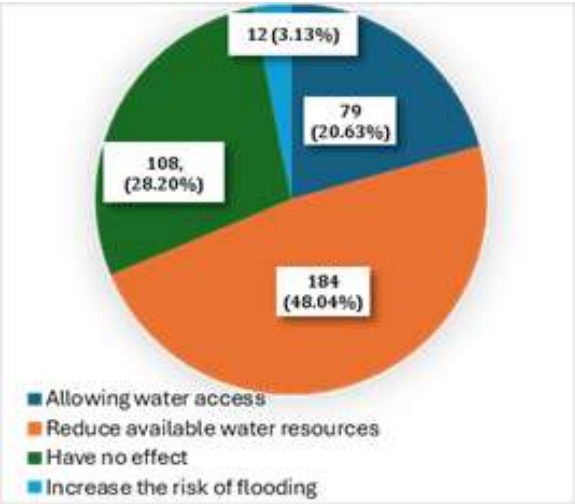

Fig. 1. The farmers' opinions concerning water access for agriculture
Source: Own processing based on field survey.

17.23% (66 farmers) pointed to a lack of fertilizers as a key issue, possibly due to rising costs or reduced availability of essential nutrients needed for crop growth, while the majority of respondents (42.04%, 161 farmers) identified soil erosion and drought as the main factor, which aligns with scientific research indicating that climate change exacerbates soil degradation and water shortages, directly impacting crop yields (Fig. 2). This emphasizes the urgent need for climate-adaptive soil conservation techniques, sustainable irrigation practices, and policies that address the increasing risks of land degradation in European agriculture.
A considerable proportion (34.99%, 134 farmers) attributed the decline to intensive agricultural practices, highlighting concerns about overexploitation of soil, monocultures, and unsustainable farming methods that deplete natural resources. A much smaller fraction (5.74%, 22 farmers) considered pesticides as a major cause, indicating that their impact on productivity is perceived as less significant compared to other factors.

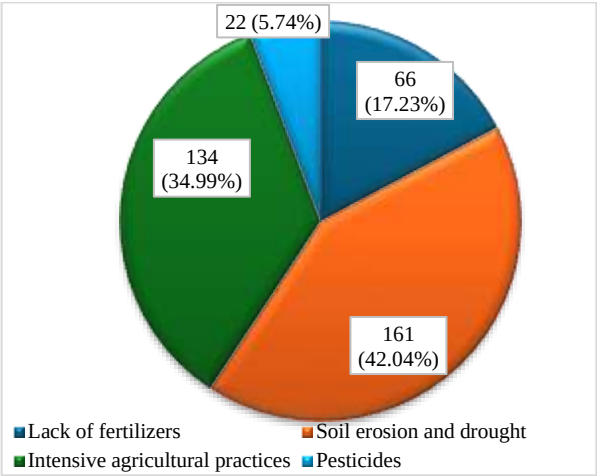

Fig. 2. The farmers' opinions concerning the main cause of the decline in agricultural productivity in the EU, in the context of climate change
Source: Own processing based on field survey.

Majority of subjects, 169 farmers, respectively (44.13%), have a correct perception meaning that climate changes promote soil nutrients depletion. 51 of the respondents representing 13.32% of the total (Fig. 3), have the misconception that climate changes contribute to the enhancement of soil nutritional status.
This approach aligns with scientific evidence, as climate change-induced factors such as soil erosion, extreme rainfall, increased leaching, and higher temperatures accelerate the depletion of vital nutrients like nitrogen, phosphorus, and potassium from the soil. It also emphasizes the urgent need for soil conservation strategies, such as cover cropping, organic amendments, precision fertilization, and reduced tillage, to counteract nutrient depletion and sustain soil fertility in the face of climate change.
A significant proportion (39.43%, 151 farmers) consider that climate change causes the accumulation of heavy metals in the soil. While this can occur in certain environmental conditions, such as increased soil acidification leading to metal mobilization, it is not the primary effect compared to nutrient depletion.

Lastly, 3.13% (12 respondents) think climate change has no effect on soil nutrient composition, which contradicts the well-documented impacts of changing climate patterns on soil health.

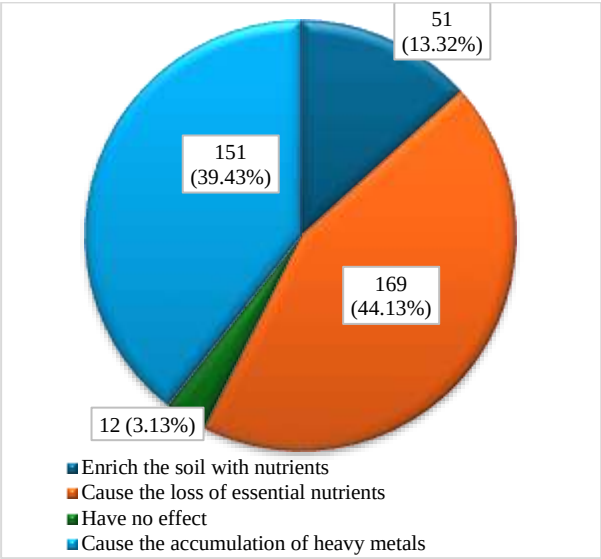

Fig. 3. The farmers' opinions concerning the way in which climate change affects the composition of soil nutrients
Source: Own processing based on field survey.

Most farmers (41.25%, 158 respondents) believe that increased temperatures enhance water access, which may reflect the perception that warmer conditions could lead to increased precipitation or improved irrigation efficiency in some regions (Fig. 4). However, this viewpoint may overlook the risk of heightened evaporation rates, which could negate any perceived benefits in water availability.

A significant portion (31.85%, 122 respondents) suggests that higher temperatures cause more vigorous plant growth.

While certain crops might benefit from extended growing seasons or increased photosynthesis, excessive heat can also lead to heat stress, reduced yields, and greater water demand.

Approximately 24.80% (95 respondents) think that increased temperatures have no effect on plant growth, possibly due to a lack of observed changes in their local context or reliance on resilient crop varieties.

Only 2.09% (8 respondents) believe that higher temperatures slow down plant growth, which is counterintuitive given that extreme heat often hinders plant development and reduces agricultural productivity (Fig. 4).

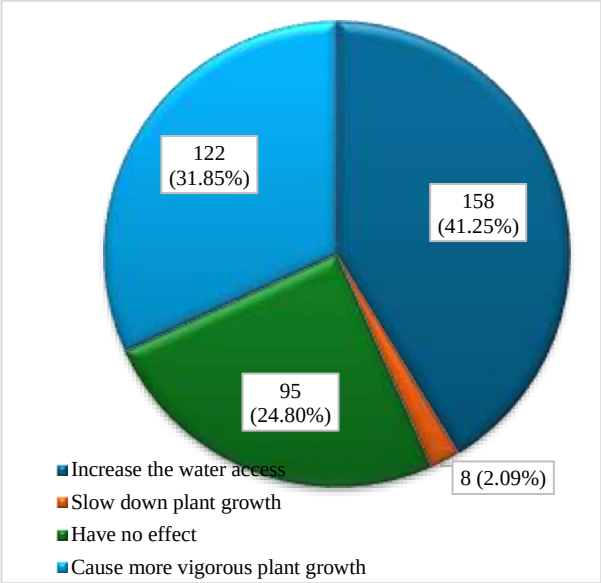

Fig. 4. The farmers' opinions concerning the effect of increased temperatures on the growth cycle of plants
Source: Own processing based on field survey.

The discrepancy between the farmers which have the correct response, and the others suggests a potential misalignment between farmers' perceptions and the scientifically established effects of temperature increases on plant growth.

The correct perception was observed at 37.08% (142 respondents), indicating that most farmers believe that the growing season is extended due to climate change (Fig. 5). This perception aligns with scientific research showing that rising temperatures and milder winters have lengthened the growing period in many European regions, allowing for longer or additional crop cycles. However, an almost equal percentage of farmers (36.81%, 141 respondents) believe that the number of crops is reduced due to climate change (Fig. 5).

While an extended season could theoretically allow for more crop cycles, increasing droughts, heat stress, and unpredictable weather patterns may limit the variety and productivity of crops, forcing farmers to focus on more resilient but fewer crop types. A smaller group of respondents (22.45%, 86 farmers) think that the growing season remains the same, which may reflect experiences in areas where climate change

impacts have been less pronounced or offset by other environmental factors.

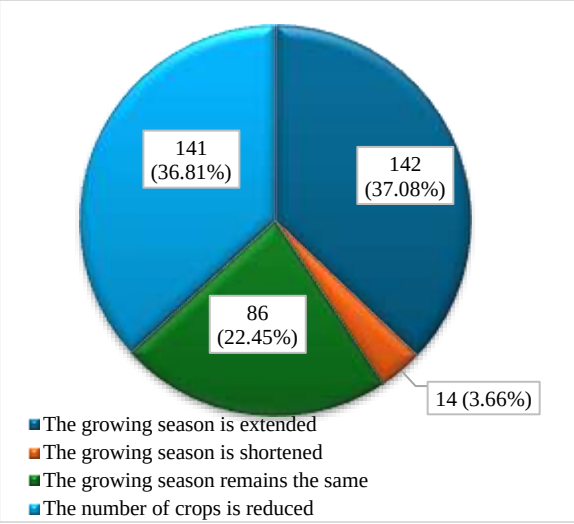

Fig. 5. The farmers' opinions concerning the changes occurring in the European agricultural season due to climate change
Source: Own processing based on field survey.

Only 3.66% (14 respondents) believe that the growing season is shortened, which is the least chosen response.

While this can happen in specific cases (e.g., extreme heat accelerating plant maturity too quickly), the general trend in Europe has been toward an extended season. The correlations between farmers' awareness concerning the influence of climatic changes on crops nutritional status variables emphasize key perceptions and misconceptions about the impacts of climate change on agricultural productivity and soil health (Table 2).

One of the strongest positive correlations is observed between "Increase the risk of flooding" and "Cause the accumulation of heavy metals" with a value of 0.53, suggesting that farmers who associate climate change with flooding are also likely to believe it leads to increased heavy metal accumulation in the soil. "Soil erosion and drought" is highly negatively correlated with "Cause the accumulation of heavy metals" (-0.91), with "Cause more vigorous plant growth" (-0.91), and with "Enriches the soil with nutrients" (-0.46) indicating that farmers have a correct perception on factors affecting the influence of climatic changes on crops nutritional status.

Table 2. The simple Spearman correlations between farmers' awareness concerning the influence of climatic changes on crops nutritional status variables

Issue	Var11	Var12	Var13	Var14	Var15	Var16	Var17	Var18	Var19	Var20
Var1	-0.15	-0.53	-0.35	0.80	0.03	-0.09	0.63	-0.26	-0.63	-0.14
Var2	0.32	0.23	0.14	-0.41	0.66	0.71	-0.28	-0.26	-0.06	0.24
Var3	0.12	-0.63	-0.04	0.28	-0.84	-0.40	0.65	-0.08	-0.34	-0.59
Var4	0.29	0.53	-0.15	-0.53	0.47	0.12	-0.49	-0.29	0.51	0.45
Var5	-0.03	-0.53	-0.39	0.75	0.14	0.02	0.64	-0.41	-0.67	-0.10
Var6	0.10	-0.29	0.63	-0.38	-0.91	-0.04	0.12	0.46	-0.05	-0.66
Var7	0.31	0.10	-0.64	0.14	0.69	0.10	0.08	-0.79	-0.03	0.45
Var8	-0.95	0.66	-0.19	0.38	0.15	-0.74	-0.61	0.76	0.74	0.56
Var9	0.35	0.44	0.29	-0.84	0.07	0.25	-0.52	0.02	0.49	0.12
Var10	0.35	-0.25	0.35	-0.20	0.32	0.85	0.15	-0.19	-0.56	-0.20

Var 1-Increase the water access; Var 2-Reduce available water resources; Var 3-Have no effect; Var 4-Increase the risk of flooding; Var 5-Lack of fertilizers; Var 6-Soil erosion and drought; Var 7-Intensive agricultural practices; Var 8-Pesticides; Var 9-Enrich the soil with nutrients; Var 10-Cause the loss of essential nutrients; Var 11-Have no impact; Var 12-Cause the accumulation of heavy metals; Var 13-Accelerate the growth cycle; Var 14-Slow down plant growth; Var 15-Have no effect; Var 16-Cause more vigorous plant growth; Var 17-The growing season is extended; Var 18-The growing season is shortened; Var 19-The growing season remains the same; Var 20- The number of crops is reduced.
Source: Own results.

A notable negative correlation is found between "Pesticides" and "Increase the water access" (-0.95), implying that farmers who see pesticides as a major issue are less likely to believe that climate change improves water availability. There is a moderate positive correlation (0.66) between "Reduce available water resources" and "Cause the accumulation of heavy metals", highlighting that farmers who recognize water scarcity as a major effect of climate change are also more likely to associate it with increased heavy metal content in soils. Below et al. (2012), analysing socio-economic variables expected to be significantly correlated with adaptation to climate changes identified weak, positive and negative correlations [5].

According to PCA, there are five principal factors (Table 3). The first principal component is associated with the influence of

climate change on water availability for agriculture in a national context, where the strongest positive loadings are observed for "Increase the water access" (0.647) and "Have no effect" (0.646), while "Increase the risk of flooding" (-0.671) has a notable negative loading. It Is responsible for the greatest part of variance, 34.66% respectively.

This suggests that farmers' perceptions regarding water availability are polarized, with some believing that climate change improves access while others associate it with risks such as flooding. The second component represents the main cause of the decline in agricultural productivity in the EU due to climate change, explaining 27.70% of the variance. "Lack of fertilizers" (0.626) emerges as the most influential factor, followed by "Soil erosion and drought" (0.276), while "Pesticides" (-0.544) has a strong negative loading, indicating that some farmers perceive it as less critical to agricultural decline compared to other factors. The third principal component focuses on how climate change affects soil nutrient composition, accounting for 20.65% of the variance.

A strong negative loading for "Cause the accumulation of heavy metals" (-0.983) suggests that farmers who recognize this impact strongly associate it with nutrient degradation rather than enrichment.

The fourth principal component, explaining 10.00% of the variance, examines the effect of increased temperatures on plant growth cycles. "Have no effect" (-0.630) has the strongest negative loading, suggesting that the belief in temperature-induced changes dominates among farmers.

Table 3. The PCA conducted for identifying farmers perception on climatic changes effects on crops nutrition

Eigenvalue	Variance, %	Factor	Item	Factor loading
6.933032	34.66516	Ease water access for agriculture and climate changes	Allowing water access	0.647428
			Reduce available water resources	-0.290922
			Have no effect	0.646140
			Increase the risk of flooding	-0.671334
5.540028	27.70014	The main cause of the decline in agricultural productivity in the EU, in the context of climate change	Lack of fertilizers	0.626288
			Soil erosion and drought	0.275732
			Intensive agricultural practices	-0.176756
			Pesticides	-0.544304
4.129992	20.64996	How climate change affects the composition of soil nutrients	Enrich the soil with nutrients	-0.583665
			Cause the loss of essential nutrients	0.257862
			Have no impact	0.489864
			Cause the accumulation of heavy metals	-0.982765
2.000432	10.00216	The effect of increased temperatures on the growth cycle of plants	Accelerate the growth cycle	0.156860
			Slow down plant growth	0.216460
			Have no effect	-0.629967
			Cause more vigorous plant growth	0.278934
1.396516	6.98258	Changes occurring in the European agricultural season due to climate change	The growing season is extended	0.949203
			The growing season is shortened	-0.393149
			The growing season remains the same	-0.936300
			The number of crops is reduced	-0.820968

Source: Own processing.

"Cause more vigorous plant growth" (0.279) and "Slow down plant growth" (0.216) both contribute positively but to a lesser extent, indicating varied perspectives on how heat influences plant development.

The final component, covering 6.98% of the variance, captures changes in the European agricultural season due to climate change. "The growing season is extended" (0.949) has the strongest positive loading, indicating widespread agreement that climate change is lengthening the farming season.

Conversely, "The growing season remains the same" (-0.936) and "The number of crops is reduced" (-0.821) exhibit strong negative loadings, reflecting the perception that seasonal shifts are occurring rather than remaining static or reducing overall crop diversity.

CONCLUSIONS

The present study reveals that nearly half of the surveyed farmers recognize that climate change reduces available water resources,

confirming the scientifically established trend of increasing water scarcity due to rising temperatures and altered precipitation patterns. Regarding agricultural productivity, soil erosion and drought are identified as the primary causes of decline, aligning with scientific research that points to land degradation and water shortages as key threats. Farmers also acknowledge the role of intensive agricultural practices, which suggests that many understand the long-term risks associated with soil overexploitation and monoculture systems. The strong recognition of nutrient loss due to extreme weather, erosion, and leaching reinforces the urgent need for soil conservation strategies, including cover cropping, organic amendments, and precision fertilization. The results also highlight discrepancies in perceptions regarding temperature increases and plant growth. While some farmers believe that higher temperatures enhance plant growth or increase water access, these perceptions may overlook the negative effects of heat stress, increased evaporation, and water scarcity. The varied responses suggest a misalignment between observed impacts and scientific evidence, emphasizing the need for more awareness-building initiatives on the true consequences of climate change for crop production. Most respondents correctly perceive an extension of the growing season, which is consistent with longer frost-free periods and warming temperatures in Europe.

The correlation analysis shows both correct perceptions and misconceptions about climate change effects on agriculture. The PCA allows us to emphasize the hierarchization of the main factors of climate changes affecting the crop nutrition in the perception of the respondents.

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