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ANALYSIS OF THE INFLUENCE OF CLIMATIC PHENOMENA ON VEGETABLE PRODUCTION

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Abstract

Vegetables are one of the basic products in human nutrition, as they provide nutrients, vitamins and minerals. Also, in addition to their nutritional role, they also have an important economic value, given the high productivity on small areas of land. However, vegetable crops, especially those that are grown in the field, are very vulnerable to certain climatic factors such as extreme temperatures, pedological drought and precipitation. This research was focused on the impact of climate change on vegetable production, with emphasis on the negative effects of temperatures and precipitation on them. At the same time, the analysis carried out in this study underlines the importance of understanding the relationship between climate variability and changes in vegetable production. To carry out the analysis in this paper, the WoS database was queried, from where the scientific works relevant to the studied topic were extracted. For the analysis of the influence of climate change on vegetable production, statistical data provided by the National Institute of Statistics were used, namely the average annual temperature and the amount of precipitation. The research method used to carry out the study was quantitative data analysis, using statistical methods. The results of the study show a moderate correlation between the climatic phenomena analyzed and vegetable production, but emphasize the complexity of the factors influencing production. In addition to climatic factors, other agronomic, economic and technological factors are equally important. In this respect, the adaptation of the vegetable sector to climate change becomes essential to ensure a sustainable agricultural system and food security.

Key words: *vegetable production, correlation, temperatures, rainfall*

INTRODUCTION

Climate change affects the entire planet, with economic, social and ecological repercussions [31]. Extreme weather events (e.g., soil drought and high temperatures) have become more frequent, directly and negatively affecting water resources and endangering ecosystems and the agricultural sector [31, 23]. All these phenomena require agriculture to adapt as quickly as possible to increasingly unpredictable weather conditions (e.g., temperature fluctuations, changes in precipitation amounts and the frequency of extreme events) [13, 2, 15, 16, 17].
With the increase in the global population, the role of agriculture becomes essential in society, the agricultural sector being responsible for providing food resources [9]. However, the agricultural sector is one of the most vulnerable sectors of the economy. Given this context, the agricultural sector is intensively studied in scientific research to assess the impact of climate change on it [20]. Research shows that food production will be strongly affected by increasing temperatures as well as the negative effects of greenhouse gases [19]. Vegetable crops have a particularly important role in the global economy due to their high yields per hectare and profitability, in addition to all this, vegetable crops also offer benefits for human health [3]. At the Romanian level, studies show that agriculture is dependent on climatic conditions, food security and the well-being of the population, these conditions being influenced by the ability of farmers to adapt to new environmental requirements. Farmers,

especially subsistence farmers, face challenges related to limited access to resources, price volatility and perishability of produce. Managing these challenges requires an integrated strategy that combines modern technologies with sustainable practices and effective public policies. At the same time, reducing the risks of global warming involves both adaptation measures and climate change mitigation actions. Given this context, farmers need to adopt solutions such as the use of resistant hybrids, the implementation of efficient irrigation systems and the adoption and use of digital technologies for permanent crop monitoring. Sustainable practices such as crop rotation and soil conservation also contribute to maintaining productivity and conserving water resources [22].

Scientific research has made progress in developing horticultural varieties that are resistant to abiotic stresses (e.g. drought, high temperatures, soil salinity and heavy rainfall) [18]. Climate change negatively impacts crop yields, livestock productivity, and farmers' incomes [18, 27, 7], and farmers' adaptation to new climatic conditions must be supported by technological progress and access to information [5, 32]. Vegetable production, carried out throughout the year in the open field or protected spaces, is influenced by factors such as water, light and nutrients.

Farmers can use these resources to change the timing of crop establishment, implement modern irrigation technologies, such as drip or sensor-controlled, and weather event warning, to identify the optimal times for sowing, harvesting or applying phytosanitary treatments [5].

Despite these efforts, farmers continue to face challenges related to limited access to market resources and information, price fluctuations and crop perishability. More effective management and appropriate public policies can support the development of this vital sector [10, 26].

Given the present context, the purpose of the paper is to qualitatively and quantitatively analyze the influence of meteorological factors on vegetable production, in the context of climate change, so as to present the relationship between climate variability and the dynamics of this agricultural sector. In the study, we aimed to highlight the way in which climatic factors are affected by vegetable production.

MATERIALS AND METHODS

In order to achieve the proposed objectives, the research had an organized approach in two stages using the quantitative research method. In the first part, the bibliometric analysis involved a review of the studies found in the Web of Science database. Bibliometric analysis is a quantitative research method, which centralizes publications according to several criteria (subject, title, keywords, authors, years, countries, etc.). This stage aimed to identify the current trends and directions of research in the field studied. Bibliometric analysis has appeared in scientific research since 1969, when Alan Pritchard used it for the first time in a scientific paper [8]. At this stage, the analysis was performed by configuring the "Topic" field in the WoS database [35], which filters the search for scientific articles by title, keywords, author, and abstract. The keywords used in the search were "vegetables" and "climate change". The search results showed a sample of 375 publications, and through the VOSviewer 1.6.19 software [34], the publication's data were presented graphically, through maps and then interpreted.

The work continues with the collection and analysis of meteorological data (precipitation, temperatures) and vegetable production, creating the possibility of making statistical correlations. The data were taken from National Institute of Statistics-NIS [21] and National Meteorological Administration (ANM) [22]. By using statistical analysis methods, such as correlation and regression, it was possible to determine the existence/non-existence of a significant relationship between environmental variables and vegetable production.

RESULTS AND DISCUSSIONS

A bibliometric study on the topic based on WoS information

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Following the keyword query, a number of 375 publications were identified in WoS, most of which were published in journals such as: Acta Horticulturae, Sustainability, Frontiers in Plant Science, Science of the Total Environment and Agriculture Basel.

WoS Publishing Dynamics

Analyzing the number of publications per year, it was observed that the first publication on the researched topic was recorded in 1979. Since 2000 (3 publications), the number of publications began to increase, reaching a maximum number of 43 publications in 2021. In 2024, 15 publications were recorded. It is important to know that the research was conducted in the middle of this year (Fig. 1).

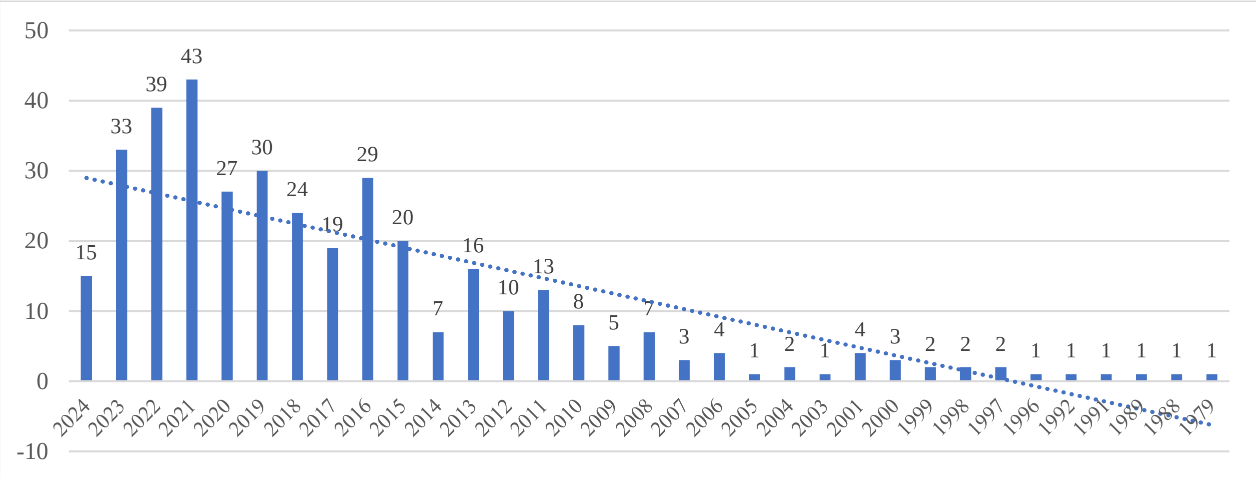

Fig. 1. Dynamics of WoS publications by keywords "vegetable" & "climatic changes" in the period 1979-2024 (number of documents/year)
Source: Own processing based on WoS results using VOSviewer [34, 35].

VOSviewer Terms Map

The main areas of research on the concepts of "vegetable" and "climate change" were extracted using the VOSviewer program and represented in the figure below. This provides an easy-to-follow summary of the most debated sub-themes and shows the correlations between them. Only the main terms are highlighted, while most remain in the background.

The term map illustrates several clusters created based on the power of word association.

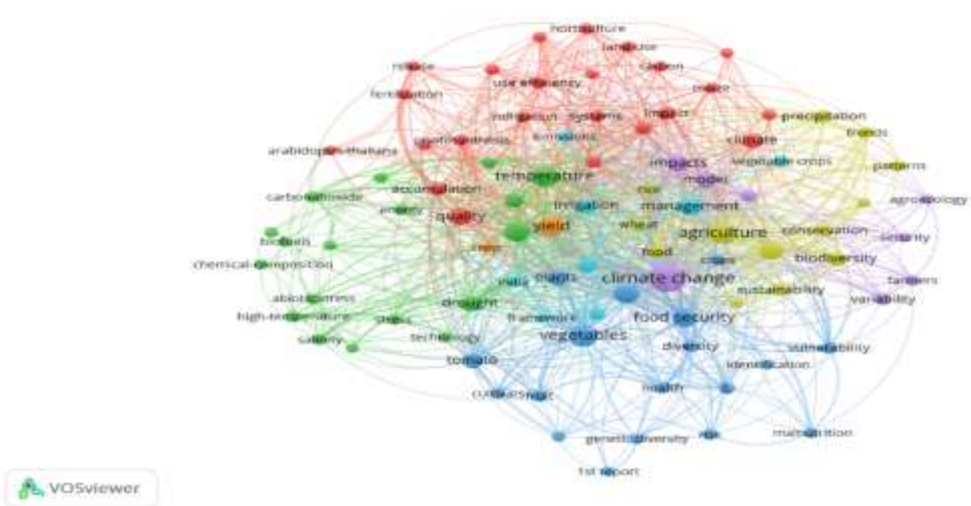

Fig. 1. Map of the correlation of the terms *"vegetable" & "climatic changes"*
Source: Own processing based on WoS results using VOSviewer [34, 35].

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The term correlation map, illustrated in the graph below, indicates seven different clusters of terms, based on their frequent use in the literature published in WoS. Some clusters are larger, such as red, green, and blue clusters, while others are smaller, such as yellow, light blue, and orange clusters.
The first cluster (red) is the one that has the highest representation and refers to the culture system. It includes 23 terms, including: horticulture, system, climate, fertilization, impact, etc.
The second cluster (green) is made up of 18 terms that belong to the field of climate change, among which we mention: temperature, carbon dioxide, energy, drought, biofuels, etc.
The third (blue) dark cluster also includes 18 terms and is located in the area of food security, among the main words found are: vegetables, fruits, vulnerability, main nutrition, diversity, etc.
The fourth cluster (yellow) is made up of 13 terms that focus around the concept of sustainable agriculture, among which we mention: agriculture, sustainability, biodiversity, food, conservation, etc.
The fifth cluster (purple) comprises 8 terms: agroecology, climate change, farmers, impact, model, productivity, security and variability. Also, the sixth cluster (light blue) also includes 8 terms: emissions, framework, greenhouse, India, irrigation, management, performance, vegetable crops. The terms in the two clusters come from the authors' various research carried out to measure the impact of climate change on the horticultural sector (Figure 1).
The graphical representation of the density generated by VOSviewer indicates the terms or keywords that have been most frequently used in the bibliographic analysis or in the research in the analyzed field. Due to the frequency of these keywords, the density map indicates areas of interest or research topics that are more important or relevant in that field. Thus, for the researched subject, the following representative words are identified: climate change, agriculture, yield, food security, management, adaptation, sustainability, sustainable agriculture and impact (Figure 2).

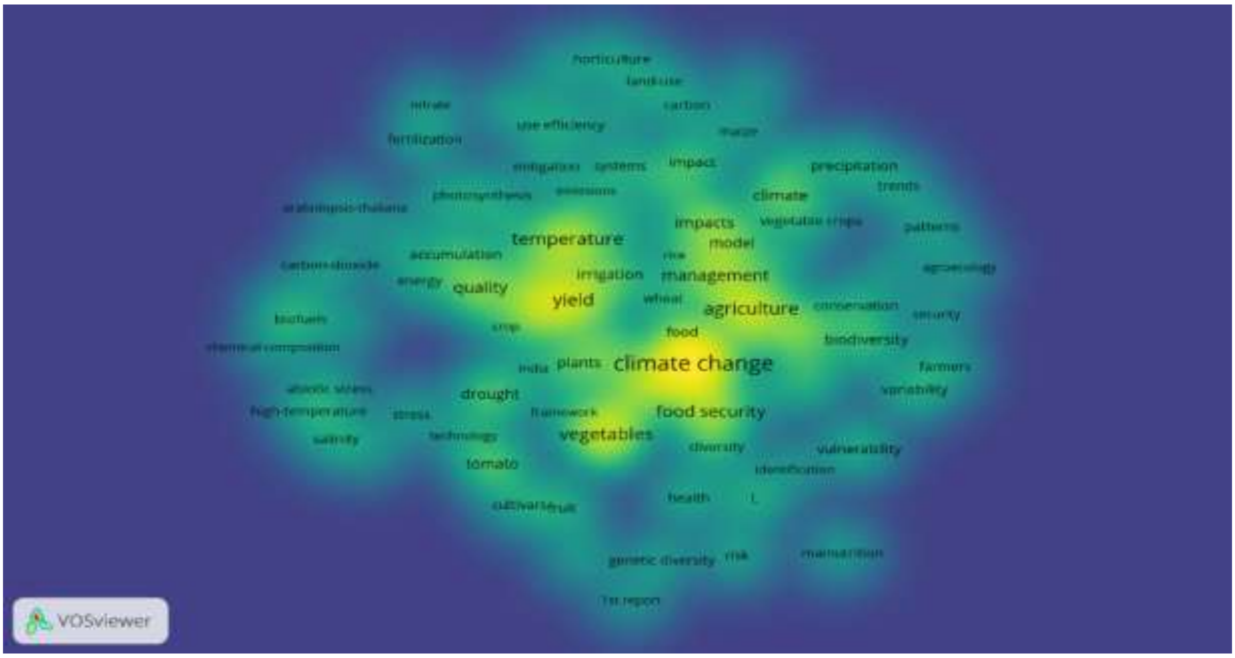

Fig. 2. Graphical representation of the density of the keywords *"vegetable" & "climatic changes"*
Source: Own processing based on WoS results using VOSviewer [34, 35].

In terms of the distribution of Web of Science publications on *"the topics of "vegetable" & "climatic changes"* by country, India is the country that registered the largest number of publications, respectively 68 publications, followed by China (41 publications), Germany (38 publications), USA (29 publications), France (18 publications) and Italy (16 publications). In In Romania, 3 publications were indexed on the analyzed topics, ranking it 45th in the top countries (Fig. 3).

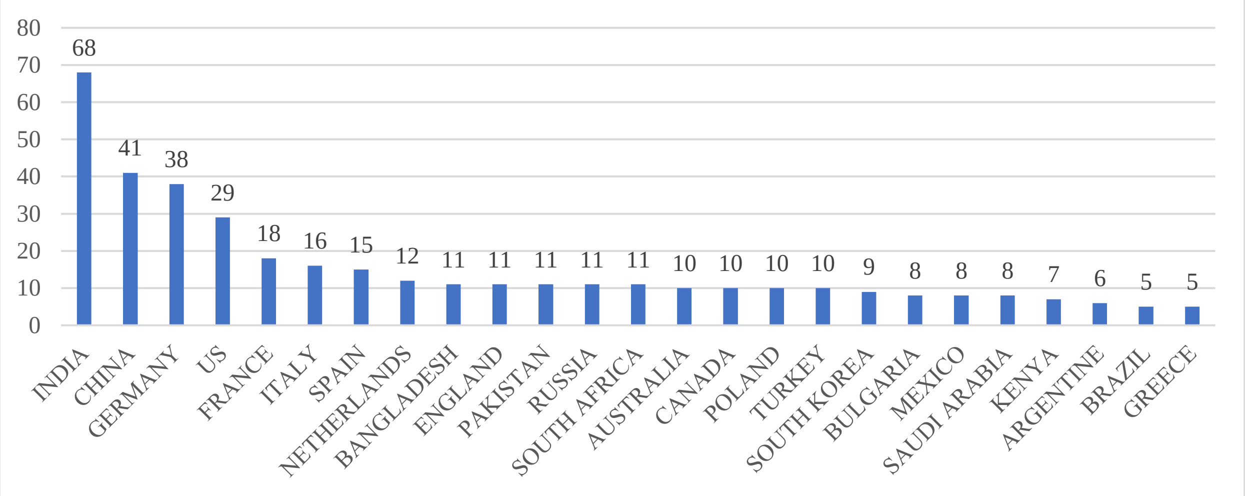

Fig. 3. Top 25 countries by number of publications in WoS by keywords
Source: own processing using excel based on WoS results [35].

The influence of climate change on vegetable cultivation

More and more research has shown that factors such as environmental pollution, increased atmospheric CO2 levels and the greenhouse effect are closely associated with climate change. Drought, high temperature and salinity are among the main environmental stressors affecting crop yields, causing a global food security crisis. These effects are even more profound when it comes to horticultural crops, which are generally more sensitive to climate change than field or tree crops [11].

According to Acikgoz (2011) [1], climate sets the limits and provides guidance on the cultivation methods of field vegetable crops as well as their cultivation time and varieties. At the same time, the author believes that field vegetables are much more vulnerable to climate change than arable crops. They are negatively influenced by temperature changes and extreme weather phenomena (e.g. drought, floods and severe storms, etc.) [12].

Considering these opinions of the author, we can state that vegetable production is directly threatened by climate change and the resistance of pathogens to phytosanitary treatments.

Influence of temperatures

Temperature fluctuations are one of the major challenges facing agriculture worldwide.

Romania has a diversified vegetable sector with a long tradition in vegetable cultivation.

The average annual temperature in Romania has increased significantly in recent decades, and seasonal fluctuations bring with them capital consequences for agricultural production. These changes influence not only the volume and quality of crops, but also consumer behavior and marketing methods.

For Romanian farmers, temperature variations affect planting and harvesting periods, increase risks related to pests and diseases, and increase uncertainty in the market.

Vegetable crops are affected by global warming, climate change, and biotic and abiotic factors [3]. According to studies, increasing temperatures directly affect photosynthesis [18] which causes changes in the content of sugars, organic acids, and vitamins [4, 19]. These changes influence the firmness and antioxidant activity of vegetables, influencing the quantity and quality of production [20, 29].

Climate change increases the frequency of disease and pest problems, leading to a decrease in production and quality. Under these conditions, vegetable cultivation becomes unprofitable. High temperatures also intensify problems related to drought and soil salinity, making vegetable cultivation difficult [3]. The most affected are vegetable crops grown in the field and only to a lesser extent those grown in protected areas [4].

Higher and higher temperatures will change agricultural production patterns. The vegetation period of the crops can influence the crops differently: for some it can be beneficial, but for others it will lead to the deterioration of production. In addition, high temperatures affect water resources, expand diseases, pests and weeds [5, 19].

The increase in temperatures causes the intensification of evapotranspiration, which causes water stress to plants, especially in dry periods. Experiments in different regions of the world have shown that increased temperatures reduce crop yields and increase production costs. Vegetables whose edible part is fruit (peppers, cucumbers, pumpkin, tomatoes, eggplant, etc.) They are particularly sensitive to heat stress, which leads to a decrease in production and a deterioration in its quality [4].

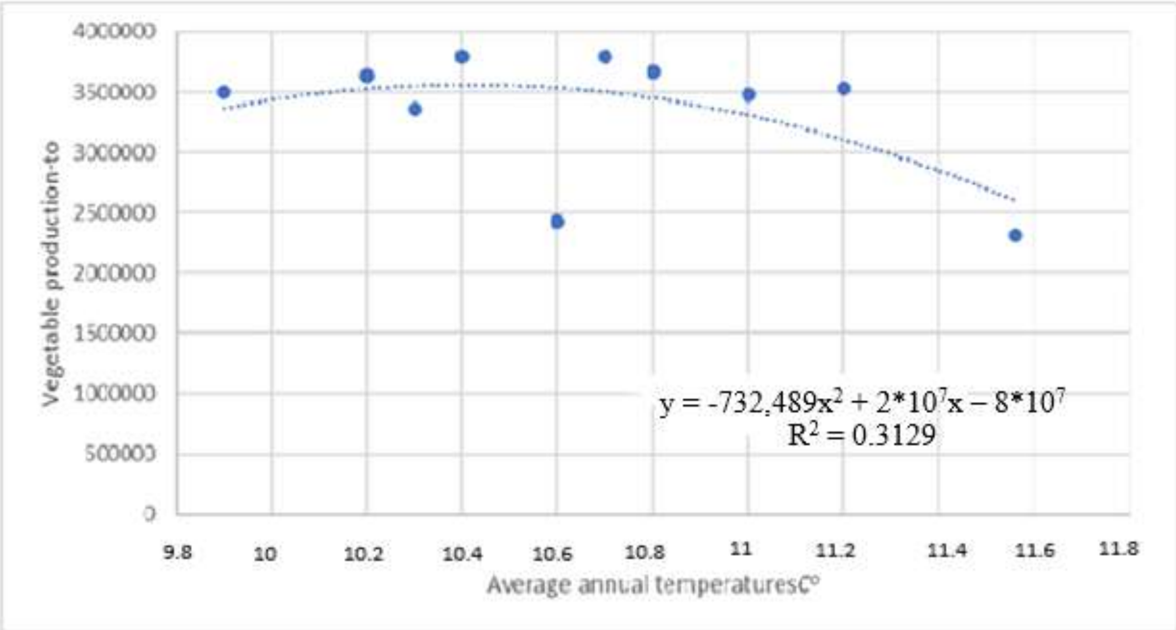

Fig. 4. Influence of average annual temperatures on vegetable production in 2015-2023
Source: own processing based on the data from [21, 22].

In order to analyze the influence of temperatures on vegetable production, NIS statistical data were used for these indicators in the period 2015-2023. The average annual air temperature had a general trend of increasing by about 1.18% annually, so that in 2023 it reached 11.56°C, 0.76°C more than in 2015.

Figure 4 illustrates the relationship between variations in average annual temperatures and vegetable production over the last 9 years, highlighting trends and the impact of climate change on vegetable growing. The trend line described by the equation $y = -732{,}489x^2 + 2*10^7x - 8*10^7$, shows that temperatures have a positive effect on production until an optimal point is reached. After this threshold, the excessive increase in temperatures causes a decrease in vegetable production.

The value of the coefficient of determination $R^2 = 0.3129$ indicates that approximately 31.29% of the variation in production is explained by temperature. This value suggests a moderate influence of temperature on production, and there are other important factors that contribute to its variations and are not included in the model, such as soil characteristics, irrigation methods, rainfall level and other technological and agricultural management factors.

Influence of precipitation

As global warming progresses, soil moisture and precipitation patterns will undergo significant changes. Climate projections

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indicate changes in precipitation patterns, both in intensity and frequency, leading to increased evaporation. While some areas will become wetter, others will experience soil moisture loss, increased erosion, and prolonged drought [5]. These changes will directly affect agriculture, a sector that uses approximately 72% of the world's freshwater extraction [6].

Water is a vital resource for agriculture, providing the soil moisture needed at different stages of plant growth. It optimizes plant metabolic processes, promotes efficient nutrient uptake, and supports root system development. Under water stress, crops undergo significant physiological changes that affect growth, leaf number, and yield [24].

Globally, water is becoming a scarce resource, disproportionately affecting regions prone to water scarcity. Many small farms, which produce over 70% of the world's food [25], are located in regions with limited access to irrigation, of which less than a third have the necessary infrastructure [33].

Studies show that climate change has an unequal impact, affecting developing countries more because resources are more limited and the capacity to adapt is lower. This amplifies the uncertainty of food supply and destabilizes markets [14, 36].

In Romania, agriculture is deeply dependent on weather conditions, and fluctuations in precipitation have a significant impact on production. In recent years, our country has experienced periods of extreme drought followed by intense floods, both of which have devastating effects on soil and crops. During periods of drought, plants suffer from water stress, and in years with excessive precipitation, floods degrade soil quality and destroy crops.

After 2000, farmers in various regions have observed a decrease in the number of rainy days and an increase in daily temperatures. Research indicates that the main barriers to adaptation to climate change are limited access to financial resources and infrastructure [28, 30]. In this context, adaptation to new climatic conditions has become a priority for farmers and policymakers [14].

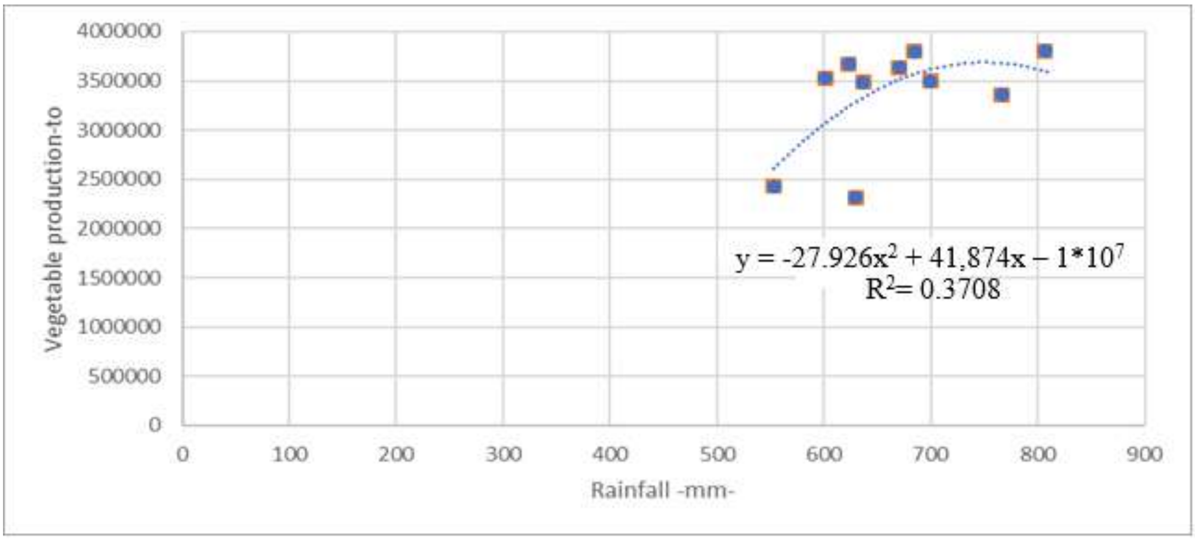

Fig. 5. Influence of rainfall on vegetable production in 2015-2023
Source: own processing based on the data from [21, 22].

In order to analyze the influence of the amount of precipitation on vegetable production, the statistical data of the NIS for these indicators in the period 2015-2023 were used. The average annual amount of precipitation has been on a downward trend in recent years, with a reduction of about 2.71% per year. In 2022, the amount of precipitation reached a minimum of 553.2 mm, a year marked by difficult climatic conditions for agriculture. Even though there was a slight increase in precipitation in 2023 (629.76), its level remains significantly lower than in 2016, when the maximum of 766.1mm was recorded.

As in the case of temperatures, Figure 5 described by the equation $y = -27.926x^2 + 41{,}874x - 1*10^7$ indicates the positive effect of precipitation on production up to an optimal point, after which excess precipitation begins to negatively affect production.

The value of $R^2 = 0.3708$ indicates that only 37.08% of the production variations can be explained by the rainfall regime, the rest being influenced by other factors.

CONCLUSIONS

The study highlights the importance of vegetables both as an essential source of food and as a valuable economic element, but which are also very sensitive to climate change. The analyzed data indicate a trend of rising temperatures, and rainfall is decreasing, factors that directly affect agriculture. Very high temperatures and uneven rainfall distribution have significantly influenced the yield of vegetable crops, this statement has also been confirmed by scientific research in the field of agricultural economics.

The results of this study show the existence of a direct link between climate variations and vegetable production, influenced by other factors, such as: soil quality and irrigation methods, which play a key role in the development of vegetable crops. This situation highlights the complexity of the relationship between the agricultural sector and climate change and the need to develop additional studies for an in-depth understanding of the interaction between natural and agronomic factors.

Adapting the vegetable sector to climate change is imperative to ensure sustainability and food security. It is also necessary to adopt a more efficient management of water resources, especially through sustainable irrigation and innovative technologies for crop protection.

Thus, to ensure sustainable agricultural production, measures must be adopted that include the development of varieties resistant to climate change.

In conclusion, the study highlights the importance of a deep understanding of the relationship between climate variability and crop dynamics to protect the agricultural sector and ensure sufficient food resources in the long term.

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