Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 1, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

# ASSESSING THE IMPACT OF CLIMATE CHANGE ON MOLDOVA'S AGRICULTURAL SECTOR: QUANTIFYING DROUGHT AND TEMPERATURE EFFECTS ON SELECTED CROPS YIELD

**Liliana CIMPOIEȘ, Maria GRUBLEAC**

Academy of Economic Studies of Moldova, 61, Mitropolit Gavriil Banulescu-Bodoni Street, Chisinau, Moldova, E-mails: lcimpoies@ase.md, grubleac.maria@ase.md

***Corresponding author***: lcimpoies@ase.md

***Abstract***

*Drought, hail, floods and heavy rains are and will represent the biggest problems that the agricultural sector will have to face due to climate change. Moldova is experiencing significant climatic variability, affecting agricultural productivity. Main agricultural crops are vulnerable to climate change. In this research, the vulnerability of main agricultural crops as wheat, maize and sunflower will be assessed to changes in factors as precipitation (drought), temperature fluctuations, and sown area. A polynomial regression model was applied. The dataset for 2007–2023 included annual yield, average temperature, precipitation level, and sown area for selected crops in the Republic of Moldova. To assess the impact of drought on the yield of particular crops, various scenarios with decreased precipitation level (20, 40 and 60%) were applied. Combined effects of drought, temperature and area was applied to simulate changes in yield for selected crops. The polynomial regression model was used to forecast the corresponding yields of wheat, maize, and sunflower after adjusting for precipitation, temperature, and area for each scenario. A heatmap was used to visualize the predicted yields of selected crops across different combinations of drought levels and temperature changes. - The results show that while temperature and precipitation effects differ by crop type, sown area is a major positive determinant of crop yields. Higher temperatures and drought conditions worsen yield declines, especially for wheat and maize, but under certain circumstances, cooler temperatures and mild drought might increase sunflower yields.*

***Key words***: *agricultural crops, climate change, maize, sunflower, wheat.*

## INTRODUCTION

Moldova's agricultural sector is important to economic development due to its contribution to GDP and providing employment to one third of population. Nevertheless, due to climate change it becomes more and more vulnerable to the effects of frequent droughts, temperature variability and changes in precipitation level. Obviously, these negative climate change effects impact agricultural productivity and yield, imposing challenges to food security and wellbeing of people living in rural areas [3, 9].

Different research results shows that extreme weather has a negative impact on crops productivity, particularly for crops as winter wheat or corn [10, 11]. According to studies, depending on drought severity, crops yield can be affected by a reduction of 10 to 50 percent [1]. These can be caused by an increase of temperature by 2 to 5 degree Celsius, imposing more challenges for farmers and requiring adapted mitigation efforts. Combined effects of heat stress and water scarcity will impact significantly on crop yields for similar regions as Moldova [8].

Different modelling techniques are used to assess the climate change impact on agricultural crops. Usually, factors as precipitation level, temperature variations and $CO_2$ concentration are used to forecast different yield scenarios in various models. Crop yields are particularly sensitive to drought and other climate changes. Lower precipitation levels will negatively impact yield, under severe drought conditions, thus is important to include drought simulations into models to assess crops vulnerability [7].

Studies suggest that extreme droughts can decrease yields in crops as maize and sunflower by 40 percent, accentuating the vulnerability of some crops to water stress [10].

Different studies suggest that addressing climate change issues require specific adapted mitigation measures [7, 8]. These solutions must be adapted and tailored for specific zones problems. To ensure productivity growth and stable food security, innovations in technology as precision agriculture and process-based crops modelling might be used. Grigoras et al [5] suggests the use of different practices to improve soil moisture retention and boost crop resilience as reduced tillage and crop residue retention. This measure could be also adapted for Moldova's agricultural sector as a measure to increase sustainability in conditions of climate vulnerability.

The aim of this paper is to assess the yield vulnerability of main agricultural crops as wheat, maize and sunflower to climate changes factors.

## MATERIALS AND METHODS

Moldova, like many other countries, is experiencing significant climatic variability, affecting agricultural productivity. Main agricultural crops are vulnerable to climate change. In this study the vulnerability of main agricultural crops as wheat, maize and sunflower will be assessed to changes in factors as precipitation (drought), temperature fluctuations, and sown area.

Different studies suggest that statistical and machine learning models to forecast yield under various climate change factors can be used [2, 4, 6, 7, 13]. Some machine learning methods focus on explaining nonlinear relationships between yield and temperature, precipitations [2]. Other studies applied fuzzy logic and regression models for crop yield predictions, by determining the direct combined effects of temperature and precipitation level on yield outcomes [4]. Among regression-based models, polynomial regression is considered efficient for modelling nonlinear relationships between yield and temperature, precipitation, area, based on historical trends to forecast yield outcome [6].

A polynomial regression model was applied to capture nonlinear relationships between yield and the independent variables (precipitation, temperature, and area). The model also included interaction terms (temperature × precipitation) to account for combined effects of these variables.

$$Yield=\beta0+\beta1\cdot Area+\beta2\cdot Temperature+\beta3\cdot Precipitation+\beta4\cdot(Temperature^2)+\beta5\cdot(Precipitation^2)+\beta6\cdot(Temperature\times Precipitation)+\epsilon$$

where:

Yield is the dependent variable in the model, while area, temperature and precipitation level are the independent variables.

Temperature² shows the nonlinear effect of temperature on yield, accounting for scenarios where temperature variations beyond an optimal range may negatively affect crop yield.

Precipitation² shows the nonlinear effect of precipitation, considering cases where excessive precipitation level could affect crop yield.

Temperature × Precipitation - represents the combined effect of temperature and precipitation on yield. This allows the model to assess whether the impact of one variable depends on the level of the other (e.g., high temperatures may exacerbate or mitigate the effects of precipitation).

$\beta0$, $\beta1$, $\beta2$, $\beta3$, $\beta4$, $\beta5$, $\beta6$ – coefficients.

$\epsilon$ - represents the random error in the model, capturing variability in yield not explained by the independent variables.

The model was fitted using historical data, minimizing the residual sum of squares between observed and predicted yields.

The dataset for 2007–2023 included annual yield, average temperature, total precipitation, and sown area for selected crops in the Republic of Moldova.

To assess the impacts of drought on wheat yield, we focus on various scenarios where precipitation decreases significantly and assessing occurred changes in yield for wheat, maize and sunflower crops. Thus, a decrease in precipitation by 20%, 40%, 60% compared to the average is examined. Based on this, yield under these reduced precipitation levels while keeping temperature and area constant at their average values is forecasted and the change in yield for each level of precipitation reduction is quantified.

To evaluate the combined effects of drought, temperature, and area, yield was simulated under various scenarios representing changes in these variables. First scenario involves drought simulation, which supposes that precipitation level was reduced by 20, 40 and 60 percent from average, for mild, moderate and severe drought case.

Second scenario implies temperature adjustment, by -1°C, 0°C, and +1°C to simulate cooler, stable, and warmer possible climate variations.

Last scenario applies changes in sown area between +10 and -10 percent variation to examine its impact on yield.

For each scenario, precipitation, temperature, and area values were adjusted, and the polynomial regression model to predict the corresponding wheat yield was used.

Interaction terms, such as temperature and precipitation, were included to capture how the combined effects of these variables influence yield. In certain cases, higher temperatures may stimulate yield loss during drought conditions.

A heatmap to visualize the predicted yields across different combinations of drought levels and temperature changes was used. The x-axis of the heatmap represents different drought levels, quantified as percentage reductions in precipitation from the historical average. The y-axis shows temperature changes in degrees Celsius (°C). The cell values represent the predicted crops yield for each scenario.

## RESULTS AND DISCUSSIONS

In the Republic of Moldova in recent years, agriculture, especially crop production, has been affected by climate change, often by droughts (once every 3-10 years). According to the State Hydrometeorological Service, the 2007 drought was one of the most severe in the history, affecting over 80 percent of the area, with losses of over 1 billion US dollars. In the same time, the drought in 2020 caused a 27.1 percent drop in global agricultural output and the loss of about 20 percent of jobs.

Crop production is exposed to natural risks, such as: natural disasters, frequent temperature fluctuations, pest attack, irregular rainfall and humidity, erosion, etc., which in turn affect the productivity of agricultural products and influence the farmers economic activity. Climate change can affect agricultural production and have a significant impact on the country's economy. Climate instability is one of the main causes of unstable harvests and poses a risk to the development of plant technology, the most vulnerable sector in agriculture. With the significant decrease in harvests, the low efficiency of their cultivation imposes questions regarding food security stability.

The dynamics of the sown areas in Moldova reflect the adaptive responses of the agricultural sector to both market and climatic challenges. Climate changes, as frequent droughts and temperature fluctuations, has significantly influenced agricultural output, causing farmers to reallocate land to more resilient or profitable crops. These changes are not only a reaction to climate change but also reflect broader economic and technological developments in the agricultural sector.

Figure 1 illustrates these changes through of the sown areas fluctuations for the main agricultural crops in the period 2007-2023, providing a more precise description of the evolution of the crop production sector in Moldova.

Analysing the dynamics of the areas sown with main crops, there is an increase in the sown area of the following agricultural crops in 2023 compared to 2007, namely: cereals and grain legumes total by 15 thousand hectares or 1.5%, total wheat by 57 thousand hectares or 18%, corn for grains by 20 thousand hectares or by 4.2%, sunflower by 158 thousand hectares or by 67.5% (Fig.1).

The areas sown with sugar beet decreased by 67.6% in 2023 compared to 2007, tobacco by 93.3%, soybeans by 50.9%, potatoes by 34.2%. Analysing the total areas sown with crops, we observe an increase of 174.3 thousand hectares in 2023 compared to 2007.

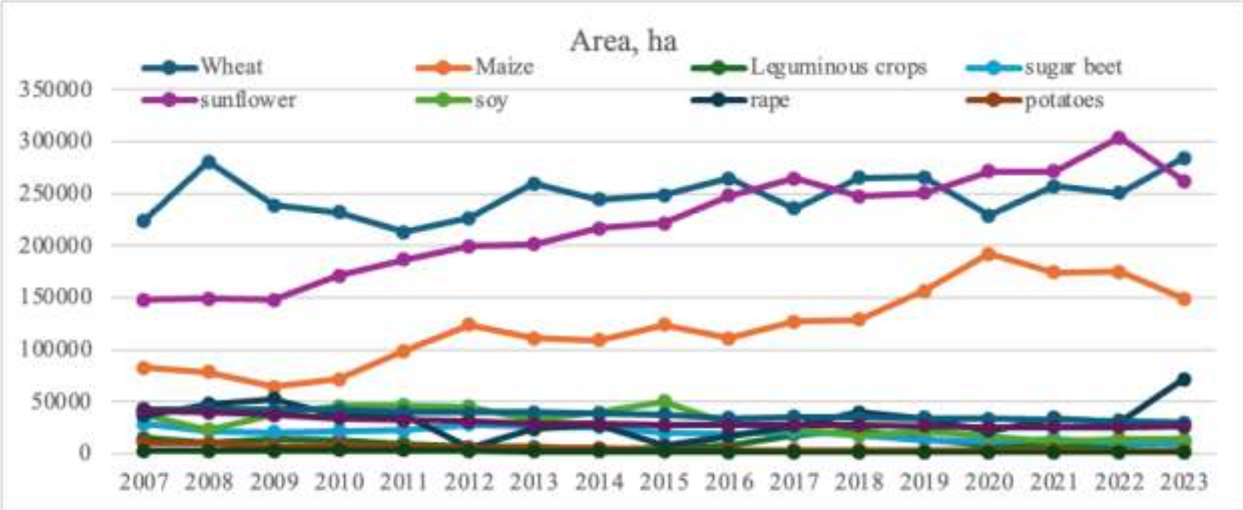


Fig. 1. Area dynamics of main sown crops in Moldova
Source: own design based on the data from National Bureau of Statistics [12].

The drought of 2007 had a considerable impact on global agricultural output, being classified as the most catastrophic in history, affecting over 80% of the territory of the Republic of Moldova. If in 2007 the global agricultural output amounted to 12,825 million MDL, in 2021 the size of this indicator increased 3.2 times, amounting to 41,017 million MDL.

The share of crop production in total global agricultural output increased by 11.6% in 2023 compared to 2007. Climate change had a considerable impact on yield of main agricultural crops (Fig. 2)

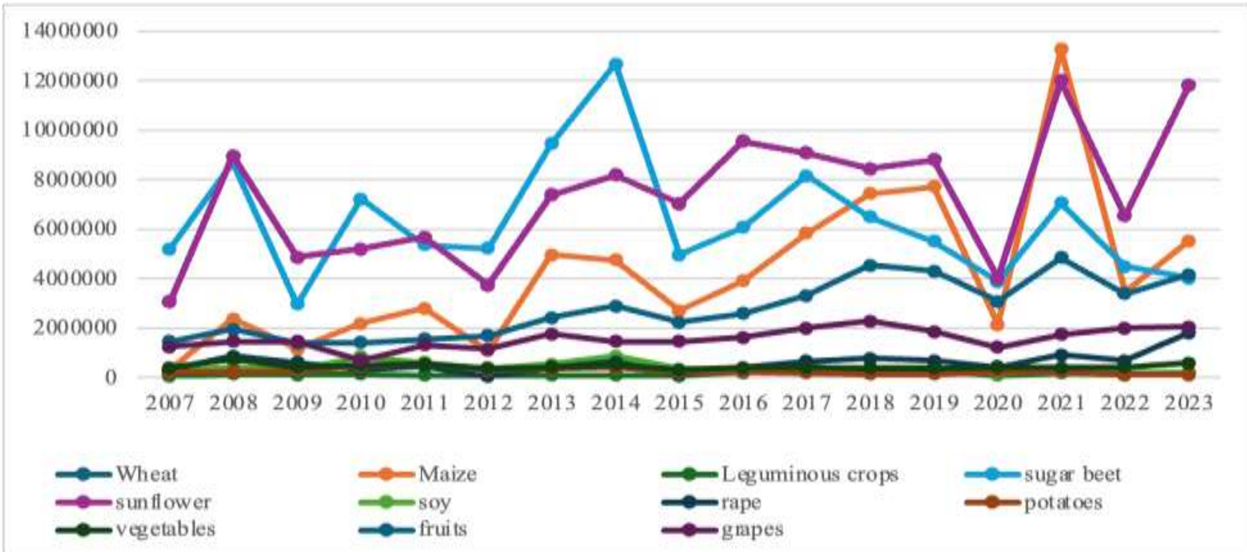


Fig. 2. Yield dynamics of main sown crops
Source: own design based on the data from National Bureau of Statistics [12].

The dynamics of the production of the main agricultural products is constantly changing, we notice that such crops as: cereals and grain legumes, including wheat, corn for grains and sunflower have registered a considerable increase from 2007 to 2023 (Fig. 2). A record harvest was obtained in 2021 for wheat 1565 thousand tons, 1158 thousand tons more than in 2007, corn grains 2793 thousand tons, 2430 thousand tons more than in 2007, sunflower 960 thousand tons, 804 thousand tons more than in 2007 and fruits, nuts and berries registering 876 thousand tons in 2021, 599 thousand tons more than in 2007. Analysing the total global agricultural output in 2023, the total harvest amounted to 9,136 thousand tons, 5,356 thousand tons or 241.6% more than 2007. Over the years, sugar beet harvest decreased by 184 thousand tons in 2023 compared to 2007, in tobacco by 3.7 thousand tons. However, the year 2021 is considered as the best harvest year within the last 30 years for Moldova.

Climate change had impacted significantly crop yields in Moldova. To assess the impact of climate change factors as temperature and precipitation level on crops yield a regression was performed. Thus, yield was considered as determinant factor, while sown area, average temperature and precipitation level were main factors on influence (Table 1).

Table 1. The influence of different factors on yield for selected crops

| Y | R | R squared | Factors of influence | Beta coefficient |
|---|---|---|---|---|
| wheat | | | | |
| Wheat Yield | 0.83 | 0.66 | Area | 113.06 |
| | | | Temperature | -1,567 |
| | | | Precipitations | -10,967.79 |
| maize | | | | |
| Maize Yield | 0.85 | 0.73 | Area | 1,061.551 |
| | | | Temperature | −61,617,030.63 |
| | | | Precipitations | 196,311.63 |
| sunflower | | | | |
| Sunflower Yield | 0.75 | 0.56 | Area | 907,430.7 |
| | | | Temperature | -1,756,753 |
| | | | Precipitations | −382,065.2 |

Source: own calculations.

The analysis of different factors as sown area, annual average temperature and precipitation level on wheat yield shows a regression result of 0.83 for wheat, indicating a moderate-to-strong relationship (Table 1). The results of R squared is 0.66, which indicates that approximately 66.17% of the variation in wheat yield is explained by the applied model. Among the influencing factors, the sown area has a positive effect on wheat yield, as an increase in the sown area leads to a corresponding rise in yield. However, temperature and precipitation levels do not appear to have a significant impact on wheat yield. Specifically, temperature does not show a statistically significant effect on yield outcomes. However, the negative coefficient suggests that higher temperatures might slightly reduce yield. Precipitation does not have a statistically significant impact on wheat yield.

For maize crops, about 73% of the variance in maize yield is explained by the polynomial regression model (Table 1). There is a positive contribution of sown area to maize yield, thus for every one-unit increase in the area sown, maize yield increases by approximately 1,061.55 units, assuming other variables remain constant. Similarly, a large positive effect is observed in relation to precipitation level, for every mm more of precipitation, maize yield increases by 196,311.63 units, assuming other variables remain constant. Regarding temperature, there is negative coefficient, thus for every one-degree Celsius increase in average temperature, maize yield decreases by approximately 61.6 million units, holding other factors constant.

In case of sunflower there is 56.1% of the variability explained by the model, while 43.9% of the variability is due to other factors not included. As the standardized sunflower sown area increases by one unit, sunflower yield is expected to increase by approximately 907,430 units, holding other variables constant.

This indicates a strong positive relationship between sown area and yield, as expected in agricultural production.

However, when temperature and precipitation increases by one standard deviation, sunflower yield decreases by about 1,756,753 and 382,065 units**,** considering all other factors constant.

This suggests that higher temperatures and excess precipitation level within the observed range negatively impact sunflower yield (Table 1).

As drought levels increase (moving from left to right), wheat yield declines significantly. At a constant temperature (zero degree Celsius), the yield drops from 5,507,416 q at 20% drought to -2,955,453 q at 60% drought (Fig. 3).

At smaller temperatures, yields are generally higher across all drought levels. This suggests that cooler conditions mitigate some of the negative impacts of reduced precipitation.

At warmer temperatures, yields are lower compared to no temperature change (0°C), highlighting the negative effects of heat on wheat under drought.

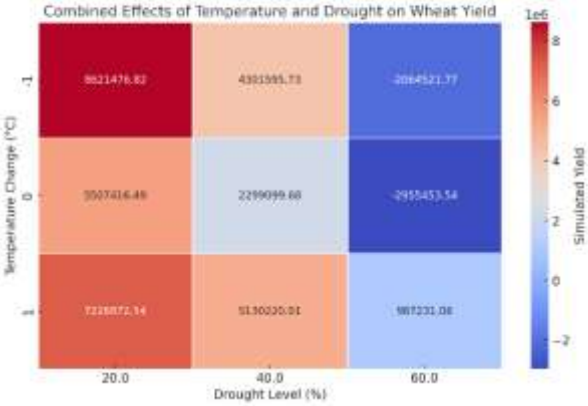


Fig. 3. Heatmap illustration of combined effects of temperature and drought on wheat yield
Source: Own calculations and processing.

The most severe yield reductions occur when high drought levels are combined with warmer temperatures.

At 60% drought and +1°C, the yield drops to 987,231 q, compared to 2,299,099 q at 0°C for the same drought level.

The combination of higher drought and warmer temperatures has a multiplicative negative effect, as seen in the severe yield reductions under these conditions.

As drought levels increase from 20% to 60% (left to right on the horizontal axis), maize yield declines significantly.

This decline is particularly pronounced under warmer temperature conditions (+1).

At lower temperatures (−1∘), yields are consistently higher across all drought levels, demonstrating the mitigating effect of cooler conditions on the adverse impacts of reduced precipitation (Fig.4).

At cooler temperatures, maize yields are the highest, even under severe drought conditions (60%).

This demonstrates the capacity of cooler climates to alleviate water stress and reduce heat-related impacts on maize growth.

At stable temperatures, yields decline more gradually with increasing drought levels, showing that reduced precipitation becomes a significant limiting factor in the absence of heat stabilizing effects (Fig. 4).

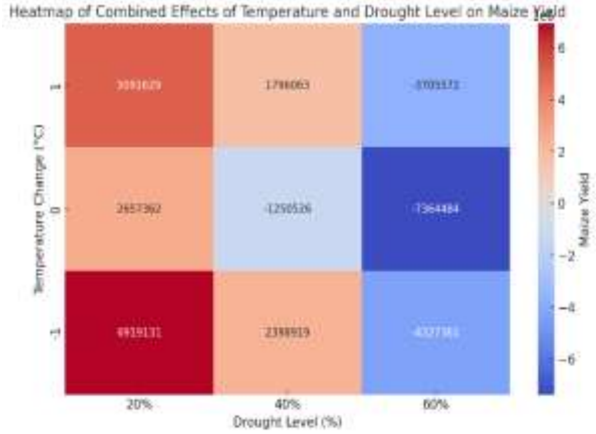


Fig. 4. Heatmap illustration of combined effects of temperature and drought on maize yield
Source: Own calculations and processing.

At warmer temperatures, the negative effects of drought are amplified. Severe drought conditions (60%) lead to negative yield reductions, demonstrating the compounded stress of high temperatures and low precipitation level.

At 20% drought, yields remain relatively stable across temperature changes, with the highest yields occurring under cooler conditions. At 40% drought, yields begin to decline more noticeably. Under warmer temperatures, maize yields drop to 1,796,063 q compared to 2,398,919 q under cooler conditions. At 60% drought, maize yields are lowest across all temperature scenarios. The combination of severe drought and warmer temperatures results in yields decreasing to -3,705,572 q, demonstrating the mixed effects of heat and low precipitation level.

The heatmap shows that sunflower yields are highly sensitive to increasing drought levels and temperature changes. Warmer temperatures tend to amplify the impact of drought, while cooler temperatures mitigate some of the yield losses caused by reduced precipitation (Fig. 5).

For sunflower, in case of mild drought (20%), yields remain relatively stable under all temperature conditions. At cooler temperatures, yields reach 6,837,873, while at warmer temperatures, yields increase to 8,293,529.

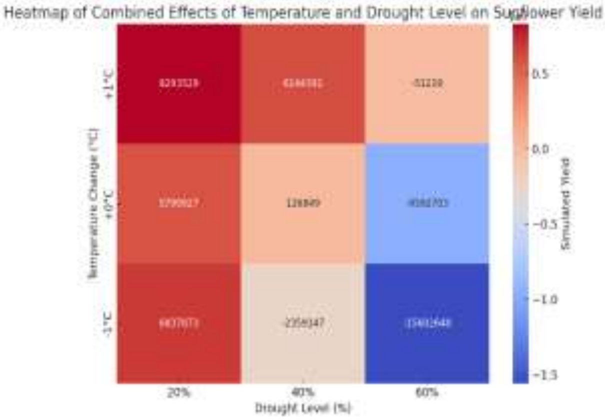


Fig. 5. Heatmap illustration of combined effects of temperature and drought on sunflower yield
Source: Own calculations and processing.

This suggests that sunflower growth may benefit slightly from mild drought under warmer conditions. In case of moderate drought sunflower yields start to show significant declines, especially at cooler temperatures where yields drop to -2,359,147. Under constant temperature, yields remain positive at 126,849, and under warmer conditions, yields improve to 6,144,391, indicating that higher temperatures may partially compensate for moderate drought stress.

Severe drought of has the most devastating effect on sunflower yields. At cooler temperatures, yields fall considerably, showing the catastrophic impact of extreme water scarcity.

Under stable and warmer (+1) conditions, yields are slightly less negative, reaching, suggesting that warmer temperatures mitigate losses to some extent but cannot offset the severe impact of drought.

## CONCLUSIONS

The analysis of wheat, maize, and sunflower yields reveals varying impacts of sown area, temperature, and precipitation. For wheat, the regression model explains 66.17% of yield variation, with sown area exerting a strong positive influence, while temperature and precipitation show minimal and statistically insignificant effects. Maize yield variation is 73% explained by the model, with sown area and precipitation contributing positively, while temperature has a significant negative impact. For sunflower, 56.1% of yield variability is attributed to the model, with sown area positively influencing yield, whereas temperature and precipitation increases negatively affect yield. Overall, sown area consistently exhibits a significant positive impact across all crops, while temperature and precipitation effects vary depending on the crop.

The research results the significant impact of drought and temperature on crop yields, emphasizing the varying sensitivities of wheat, maize, and sunflower to these stressors. Wheat yields decline markedly with increasing drought severity, particularly under warmer temperatures, where the combination of high drought and heat has a multiplicative negative effect. Cooler temperatures mitigate some of the drought impacts but cannot fully offset severe water scarcity. For maize, yields similarly decline with increasing drought, with cooler temperatures alleviating water stress and heat amplifying drought-related losses. Severe drought coupled with higher temperatures results in the steepest yield reductions. Sunflower yields are highly sensitive to both drought and temperature changes, with moderate drought showing mixed effects where warmer conditions partially mitigate yield losses. However, severe drought causes catastrophic yield declines across all temperature scenarios, though warmer conditions slightly reduce the severity of these losses. Overall, the results suggests the importance of cooler temperature regimes in moderating drought impacts and the compounded stress caused by the combination of high temperatures and severe drought.

## REFERENCES

[1]Corobov, R., 2002, Estimations of climate change impacts on crop production in the Republic of Moldova, GeoJournal, 57(3), 195–202. https://doi.org/10.1023/B:GEJO.0000003612.11530.bf Accessed on December 2, 2024

[2]Crane-Droesch, A., 2018, Machine learning methods for crop yield prediction and climate change impact assessment in agriculture, Environmental Research Letters, 13(11), 114003. https://doi.org/10.1088/1748-9326/aae159 Accessed on December 2, 2024

[3]Eitzinger, J., Trnka, M., Semerádová, D., Thaler, S., Svobodová, E., Hlavinka, P., Šiška, B., Takak, J., Malatinska, L., Novakova, M., Dubrovsky, M., Zalud, Z., 2013, Regional climate change impacts on agricultural crop production in Central and Eastern Europe – Hotspots, regional differences and common trends, The Journal of Agricultural Science, 151(6), 787–812. https://doi.org/10.1017/S0021859612000767 Accessed on December 5, 2024

[4]Garg, B., Aggarwal, S., Sokhal, J., 2018, Crop yield forecasting using fuzzy logic and regression model, Computers & Electrical Engineering, 67, 383-403.

[5]Grigoras, M., Popescu, A., Negrutiu, I., Gidea, M., Ioan, H.A.S., Pamfil, D., 2013, Effect of no-tillage system and fertilization on wheat production, Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41(1), 208–212. https://www.notulaebotanicae.ro/index.php/nbha/article/view/9109 Accessed on December 2, 2024

[6]Janmejay Pant, Pant, R.P., Singh, M.K., Singh, D.P., Pant, H., 2021, Analysis of agricultural crop yield prediction using statistical techniques of machine learning, Materials Today: Proceedings, 46(20), 10922-10926. https://doi.org/10.1016/j.matpr.2021.01.948 Accessed on December 3, 2024

[7]Li, Y., Ye, W., Wang, M., Yan, X., 2009, Climate change and drought: a risk assessment of crop-yield impacts, Clim Res, 39, 31–46. https://doi.org/10.3354/cr00797 Accessed on December 2, 2024

[8]Müller, C., Bondeau, A., Popp, A., Waha, K., Fader, M., 2010, Climate change impacts on agricultural yields: Background note to the World Development Report 2010, World Development Report, 11, 1996-2005. https://www.researchgate.net/publication/270396831_Climate_Change_Impacts_on_Agricultural_Yields_Background_Note_to_the_World_Development_Report_2010 Accessed on December 3, 2024.

[9]Nirean, E., 2013, The impact of natural risks on agricultural development of the Republic of Moldova, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development," 13(2), 295–300. https://managementjournal.usamv.ro/index.php/scientific-papers/336-the-impact-of-natural-risks-on-agricultural-development-of-the-republic-of-moldova Accessed on December 2, 2024

[10]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2020, Variation of the main agricultural crops yield due to drought in Romania and Dobrogea region in the period 2000–2019, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development," 20(4), 397–416. https://managementjournal.usamv.ro/index.php/scientific-papers/2364-variation-of-the-main-agricultural-crops-yield-due-to-drought-in-romania-and-dobrogea-region-in-the-period-2000-2019 Accessed on December 2, 2024

[11]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2023, Climate change and its impact on wheat, maize and sunflower yield in Romania in the period 2017–2021, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development," 23(1), 587–602. https://managementjournal.usamv.ro/pdf/vol.23_1/Art63.pdf Accessed on December 2, 2024.

[12]The Republic of Moldova, National Bureau of Statistics, 2024, https://statistica.gov.md/en, Accessed on December 2, 2024.

[13]Zhang, Y., Zhao, Y., Chen, S., Guo, J., Wang, E., 2015, Prediction of maize yield response to climate change with climate and crop model uncertainties, Journal of Applied Meteorology and Climatology, 54(4), 785–794. http://www.jstor.org/stable/26178306 Accessed on December 4, 2024