Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIV, 2025
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

STUDY ON THE DYNAMICS OF CEREALS CULTIVATED IN TULCEA COUNTY IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

Climate change in recent decades has had a significant impact on Romanian agriculture. In this context, Tulcea County, located in the south-eastern part of the country, has experienced a trend of increasing average annual temperatures, an increase in the number of days with temperatures above 30°C and a decrease in total annual precipitation. The study analyzed meteorological data, the evolution of crop structure, cultivated area, and yield trends over a 20-year period (1994-2023). The results showed an increase in average annual temperature from 12.39°C in 1994 to 13.8°C in 2023. Precipitation was low and showed significant variability, ranging from 215.8 mm in 2022 to 732 mm in 1997, with uneven distribution during the crop growing season. The area planted with cereals for grain varied considerably, influenced by both the predicted climatic conditions and the extent of irrigated land. Statistical analysis was performed using the Python software package, applying Pearson correlation tests to examine the relationship between climatic variables and agricultural yields. Linear regression methods were also used to identify long-term trends. The statistical tests showed that both increasing temperatures and decreasing precipitation were correlated with declining maize and wheat yields, highlighting the vulnerability of agriculture to climate change. Maize production ranged from a minimum of 323 kg/ha in 2003 to a maximum of 8,820 kg/ha in 2018. The overall trend indicates a slight decrease in average production ($R^2 = 0.41$, $p < 0.05$), correlated with increasing temperatures. Wheat showed a more stable yield, reaching a maximum of 4,738 kg/ha in 2021. The production trend was positive in periods with moderate rainfall ($R^2 = 0.63$, $p < 0.01$).

***Key words**: climate change, cereals, precipitation trends, heat stress, crop yields.*

INTRODUCTION

Tulcea County, located in the eastern part of Romania, represents a region characterized by an arid climate and an agriculture that has devolved significantly throughout history. With an agricultural area of approximately 303.2 thousand hectares, the region faces challenges related to climate change, such as rising temperatures, decreasing precipitation, and the increasing frequency of extreme weather events.

Agricultural activity in the region has been documented since prehistoric times, with evidence coming from both historical records and archaeological sites. The Greek historian Apollonius of Rhodes, in the *Argonautica*, describes how Jason's sailors, while navigating the Danube Delta via the "Beautiful Arm" - probably the present-day Sfântu Gheorghe Arm - encountered flocks of sheep and shepherds, indicating early pastoral activity in the area (Filipescu, 1928; Lup, 2003). In addition, archaeological excavations in the ancient settlement of Hamangia (modern Baia, Tulcea County) provide tangible evidence of the Hamangia culture, a Neolithic civilization that flourished between the 4th and 2nd millennia BC, demonstrating an early reliance on agriculture and animal husbandry (Hasotti, 1997). These historical and archaeological findings underscore the deep-rooted agricultural traditions of the region, providing context for its long-standing adaptation to environmental and climatic changes (Lup, 2012).

Extensive international research highlights the profound impact of climate change on agriculture, particularly in arid and semi-arid regions (IPCC, 2021). The presence of water is inextricably linked to crop production in agricultural systems (Dușa & Stan, 2022).

Rising temperatures and declining water availability have been linked to reduced agricultural productivity and shifts in crop composition (Lal et al., 2007; Rosenzweig et al., 2001; Horoiaş et al., 2013; Ciocan et al., 2024). However, while these studies provide valuable insights at a global and regional scale, they often lack localized assessments that account for specific crop responses and tailored adaptation strategies at the county level. Tulcea County, characterized by significant climatic variability, remains underrepresented in such analyses despite its agricultural importance.

This study aims to address this gap by evaluating long-term climate trends and their direct impact on cereal yields (wheat, maize, and barley). By providing a data-driven, localized perspective, the research contributes to a deeper understanding of climate-induced shifts in cereal production and informs the development of adaptive strategies for sustainable agriculture in vulnerable regions.

To achieve these objectives, this study integrates Pearson correlation analysis and linear regression modeling to quantify the relationships between temperature, precipitation, and crop productivity. The findings indicate a significant correlation between rising temperatures and declining maize yields, while wheat production shows a more stable trend, benefiting from moderate precipitation levels. By highlighting these climate-yield interactions, the study provides valuable insights for policymakers and farmers in developing targeted adaptation measures and sustainable agricultural strategies in response to ongoing climate variability.

MATERIALS AND METHODS

To analyze the impact of climate change on the dynamics of cultivated cereals, data from multiple official sources were utilized. Meteorological data for the period 1994-2023, including annual average temperatures, total annual precipitation, and the number of days with temperatures exceeding 30°C, were obtained from National Institute of Statistics (INS, 2023b). Agricultural data, covering cultivated areas and average cereal yields per hectare, were extracted from the Statistical Yearbooks of Romania and the archives of the Tulcea County Directorate of Statistics (INS, 1990; 2023a). Additionally, information regarding land use and irrigation infrastructure was sourced from the National Agency for Land Improvements.

Statistical analysis was conducted using the Python software package, applying Pearson correlation tests to examine the relationship between climate variables and agricultural yields. Linear regression methods were also used to identify long-term trends.

RESULTS AND DISCUSSIONS

The climate of Tulcea County is characterized by a warm and dry climate, specific to areas with the most generous thermal resources but also the lowest precipitation levels compared to other regions of the country. A 30-year climatic analysis shows the following: the annual average temperature is 12.03°C, the average annual precipitation is 488.79 mm, and the average number of days with temperatures exceeding 30°C is 42.4 days per year.

During the 1994-2003 period, statistical analysis highlighted significant fluctuations in annual average temperatures, as illustrated in Figure 1. The year 1994 was characterized by a high annual average temperature of 12.39°C, marked by favorable climatic conditions. However, the 1995-1997 period experienced a notable decline in annual average temperature, from 11.27°C (1995) to 10.49°C (1997), the lowest recorded value in the analyzed period. These values were influenced by negative temperatures in January and December. Between 1998 and 2002, a progressive increase in temperature was observed, from 11.51°C (1998) to 12.27°C (2002), followed by slight variations between 11.68°C and 11.73°C in 2000-2001. In contrast, the year 2003 was notable for a drop in the annual average temperature to 10.78°C, driven by the low temperatures recorded in January (-1°C) and February (-4.5°C).

Between 2004 and 2023, statistical analysis identified the following trends: the years 2004-2006 and 2011 had annual average temperatures varying between 11.18°C (2011) and 11.59°C (2004), marking lower values compared to the subsequent period. The 2007-2013 period saw a significant increase in temperatures, ranging from 12.03°C (2007) to 12.43°C (2013). Similarly, the years 2014-2023 recorded annual average temperatures consistently above 12°C, reaching a peak of 13.80°C in 2023. During this period, 2019-2023 had the highest temperatures, all exceeding 13°C.

Data analyzed from 1994 to 2023, using linear regression tests, indicate a significant upward trend in annual average temperatures (R^2 = 0.84, $p < 0.01$), increasing from an average of 11.27°C in 1995 to 13.8°C in 2023. This increase has been associated with a rise in the number of heatwave days, reaching 65 days in the years 2012 and 2022.

Moreover, the length of the growing season for key cereal crops, such as wheat, corn, barley, sunflower, and peas, has been affected by these changes, leading to earlier planting and harvesting periods.

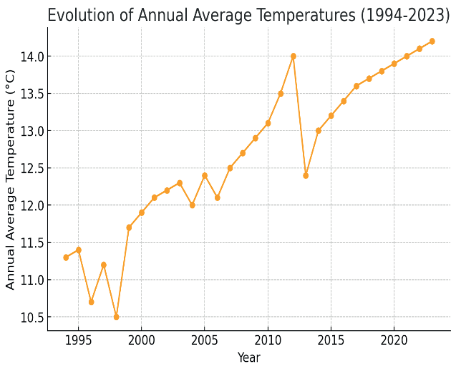

Figure 1. Evolution of annual average temperatures between 1994 and 2023

The period analyzed showed a decreasing trend in precipitation, as illustrated in Figure 2. Notably, between 1994 and 2003, annual precipitation varied from a minimum of 298.1 mm in 2003 to a maximum of 732 mm in 1997. In addition to temperature variations, the precipitation regime has also undergone significant changes. The analysis of rainfall data between 1994 and 2023 indicates a gradual decrease in annual precipitation from 480 mm in 1994 to 430 mm in 2023. This downward trend has contributed to an increased risk of drought and a reduction in soil moisture levels, impacting agricultural productivity. Years of drought, including 2003, 2004, 2009, 2011, and 2012, experienced total annual precipitation below 300 mm. Additionally, from 2014 to 2020, annual precipitation remained below 400 mm, impacting cereal crop yields and prompting the adoption of adaptive irrigation systems. The correlation with agricultural yields indicated that insufficient precipitation during drought years significantly reduced crop productivity. From 2004 to 2023, the declining trend persisted, with annual average values remaining below 488.79 mm. Notably, in 2022, precipitation dropped to just 215.8 mm. Linear regression analysis showed a moderate but significant decrease in precipitation (R^2 = 0.59, $p < 0.05$), declining from an average of 488.79 mm per year to values below 300 mm in drought years, such as 2022.

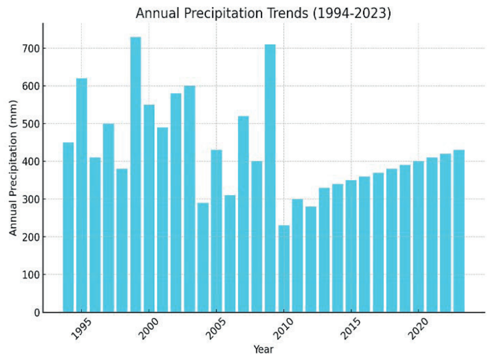

Figure 2. Evolution of average annual precipitation between 1994 and 2023

Along with high temperatures and low precipitation, the frequency of days with temperatures exceeding 30°C also contributes to the arid climate of Tulcea County. Notable instances were recorded in 1995, 1997, 2004, and 2005, with 25 days in 1995, 10 days in 1997, 13 days in 2004, and 24 days in 2005. During the rest of the analyzed period, the number of such days ranged between 30 and 65, including 60 days in 2016 and 2018, 62 days in 2019, and 65 days in both 2012 and 2022 (Table 1). In years with a high frequency of extremely hot days, these events were primarily concentrated between June and September.

The increase in the number of extreme weather events, including heatwaves, storms, and prolonged dry spells had led to higher evapotranspiration rates, negatively impacting plant growth cycles and increasing the demand for soil conservation techniques, such as no-tillage farming and mulching.

Table 1. Number of days with temperatures exceeding 30°C in Tulcea County (1994-2023)

Year	No. of days	Year	No. of days	Year	No. of days
1994	34	2004	13	2014	40
1995	25	2005	24	2015	51
1996	31	2006	27	2016	60
1997	10	2007	57	2017	46
1998	31	2008	44	2018	60
1999	43	2009	39	2019	62
2000	36	2010	50	2020	57
2001	48	2011	43	2021	45
2002	43	2012	65	2022	65
2003	37	2013	42	2023	43

To evaluate the impact of climate conditions on agricultural yields, Pearson correlation tests were applied between annual average temperatures, annual precipitation, and the average yields of the main agricultural crops in Tulcea County. Additionally, linear regression analyses were conducted to identify long-term trends. These characteristics highlight the challenges associated with managing agriculture in this region, where high temperatures and precipitation deficits significantly affect crop production.

Statistical tests showed that both rising temperatures and decreasing precipitation levels are correlated with declining maize and wheat yields, emphasizing the vulnerability of agriculture to climate change.

Cultivated cereal areas have varied significantly, influenced by climate conditions. The areas cultivated with grain cereals showed notable variations depending on the evolution and forecast of climatic conditions. Available data indicates a direct correlation between fluctuations in annual average temperatures, precipitation levels, and the dynamics of cultivated areas.

Favorable annual average temperatures, ranging between 10.49°C (1997) and 12.18°C (1999), combined with precipitation levels between 454.3 mm (1995) and 640.9 mm (1999), supported the stability of cultivated areas. Thus, in 2000, the total area cultivated with grain cereals reached 162,310 ha, increasing further to 181,463 ha in 2001.

The year 2001 was marked by low precipitation (419.3 mm) and an annual average temperature of 11.73°C, as well as an increase in the number of days with temperatures above 30°C (48 days, compared to 10-36 days in previous years). These climate conditions led to a reduction in cultivated areas in 2002 to 166,001 ha.

The decline in precipitation and the rise in annual average temperatures continued to influence cultivated areas, reaching a minimum of 118,948 ha in 2007, a year characterized by average temperatures above 12°C and below-average precipitation levels.

Favorable precipitation and stable annual temperatures, ranging from 12.03°C to 12.30°C, led to a slight increase in cultivated area between 2008 and 2009, reaching values of 151,772-154,447 ha. During 2012-2013, cultivated areas increased significantly, reaching 181,757 ha in 2012 and 179,691 ha in 2013, due to a rise in precipitation from 537.9 mm in 2012 to 671.1 mm in 2017.

Between 2014 and 2023, annual average temperatures consistently exceeded 12°C, peaking at 13.8°C in 2023. Although cultivated areas temporarily increased from 151,986 ha in 2014 to 158,164 ha in 2018, severe drought and irregular precipitation patterns caused a decline to 131,884 ha by 2022 (Table 2).

An analysis of the crop structure indicates that wheat consistently ranked first in cultivated areas, primarily due to its greater drought resistance compared to maize. The area dedicated to wheat cultivation varied from 43,023 ha in 2004 to 92,120 ha in 2023. During periods of low precipitation, wheat occupied larger areas due to its ability to withstand drought conditions. The correlation between wheat cultivated area and annual temperatures was positive ($\rho = 0.52$, $p < 0.05$).

Maize was more sensitive to climatic conditions, with cultivated areas fluctuating between 29,458 ha (2010) and 90,487 ha (2004), depending on water availability forecasts. Due to maize's greater sensitivity to climatic conditions, its cultivated areas showed significant variations, with a strong correlation between cultivated area and annual precipitation ($\rho = 0.76$, $p < 0.01$).

Due to the arid climate, rye found a place in this region, although the cultivated areas remained small, ranging between 15 ha (2000) and 200 ha (2023).

Barley and spring barley, being short-cycle crops with good resistance to high temperatures, heat waves, and drought, were cultivated on fluctuating areas between 2000 and 2023. However, the ratio between barley and spring barley changed over time based on economic demands.

Table 2. Structure of source cultivated areas with Grain Cereals in the period 2000-2023 (hectares)

Year	CROP									
	Total cereals	Common wheat	Durum wheat	Rye	Barley	Spring barley	Oats	Maize grain	Triticale	Sorghum
2000	162310	60644	-	15	7914	6580	5190	81967	-	-
2001	181463	81582	311	25	12258	5930	3445	77912	-	-
2002	166001	76389	-	17	9079	8868	6271	65377	-	-
2003	134619	46855	30	24	1815	7614	5620	74476	-	-
2004	145300	43023	-	40	-	9188	4562	90487	-	-
2005	140752	60901	-	80	5741	13959	4873	55198	-	-
2006	118104	46348	17	110	2616	10229	3952	54832	-	-
2007	118984	56968	233	20	4125	12529	2089	43020	-	-
2008	151772	84199	538	50	6681	10352	3898	45454	-	-
2009	154447	76272	811	150	12165	20548	3952	40549	-	-
2010	143757	72619	2087	97	15299	19282	4570	29458	-	-
2011	144799	62530	344	169	12910	8083	3948	56815	-	-
2012	181757	90180	1225	107	15014	8098	6219	60914	-	-
2013	179691	87536	1123	113	15169	8843	6200	60707	-	-
2014	151986	80875	177	81	14856	5524	2353	48120	-	-
2015	152653	78869	425	107	16084	4073	1869	51226	-	-
2016	165614	84719	3632	117	20636	4363	1787	50360	-	-
2017	152624	83957	22	115	16777	6441	1998	43314	-	-
2018	158164	83984	575	92	18518	4567	1670	48758	-	-
2019	165660	85717	2865	121	19785	4119	1988	51065	-	-
2020	158547	84694	1194	117	17631	4538	1274	46256	2694	149
2021	136153	76533	199	269	18811	1741	274	36977	1200	150
2022	131884	76525	194	152	14493	2697	336	36197	800	490
2023	174770	92120	-	200	26000	3400	700	50500	1300	550

Source: National Institute of Statistics, Romania. County Directorate for Agriculture – Tulcea. *Statistical Data (1994-2023).*

Since 2020, a new cereal, triticale, known for its drought and heat resistance, was introduced, with cultivation areas of 2,694 ha (2020), 1,200 ha (2021), 1,300 ha (2023), and only 800 ha (2022). The cultivated areas for triticale varied between 800 ha and 2,694 ha, while sorghum cultivation increased to 550 ha in 2023. The introduction of sorghum and triticale starting from 2020 reflects farmers' adaptation to arid conditions, as these crops are more drought resistant.

The average grain cereal yields in the period 2000-2023 were strongly influenced by climatic conditions, experiencing significant fluctuations. The lowest yields per hectare were recorded in 2003 and 2007, primarily due to high spring temperatures, which led to early drought onset. During May and June, tropical temperatures were reported, combined with very low precipitation levels.

Rye recorded a minimum yield of 958 kg/ha in 2003, while barley had a yield of 977 kg/ha in 2007, marking the lowest production levels for these crops during the analyzed period.

The increase in annual average temperatures and decrease in precipitation levels prompted the introduction and expansion of drought resistant crops, such as sorghum and triticale. These crops have demonstrated superior adaptability to thermal and hydric stress.

In 2018, the average maize yield reached a peak of 8,820 kg/ha, due to favorable climatic conditions, with moderate temperatures and adequate precipitation during the growing season. Maize yields fluctuated from a

minimum of 323 kg/ha in 2003 to a maximum of 8,820 kg/ha in 2018.
The overall trend indicates a slight decline in average yield ($R^2 = 0.41$, $p < 0.05$), correlated with rising temperatures. Wheat showed more stable yields, reaching a maximum of 4,738 kg/ha in 2021. The yield trend showed a positive correlation during periods of moderate precipitation ($R^2 = 0.63$, $p < 0.01$) (Figure 3).

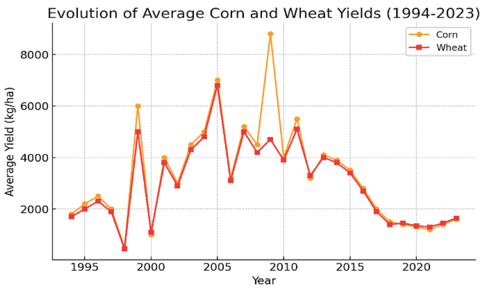

Figure 3. Evolution of average yield per hectare for corn and wheat crops between 1994-2023

The maximum wheat yield, of 4,738 kg/ha, was recorded in 2021, a year that also saw high yields for other crops: barley: 4,121 kg/ha, oats: 2,454 kg/ha, rye: 3,948 kg/ha, triticale: 3,925 kg/ha, and sorghum: 3,800 kg/ha (Table 3).
The agricultural yields in Tulcea County reflect the direct impact of climatic conditions on cereal crops. Drought years, characterized by high temperatures and insufficient precipitation, have significantly reduced yields, particularly for maize.
Adapting to climate change through the expansion of drought-resistant crops, the use of irrigation technologies, and the selection of high-performance varieties remains an essential strategy for ensuring the sustainability of agriculture in the region.
A strong negative correlation was found between annual average temperatures and average cereal production. This analysis suggests that annual average temperatures differently influence the production of corn and wheat, which is relevant for agricultural strategies and adaptation to climate change. Key observations: corn is negatively affected by temperature increases above 12°C, with a significant negative correlation ($\rho = -0.20$, $p < 0.01$). This can be explained by its high sensitivity to drought and heat stress, which can reduce yield. Wheat adapts better to rising temperatures, showing a moderate positive correlation ($\rho = 0.48$, $p < 0.05$). In the case of corn, there is a negative correlation ($\rho = -0{,}20$, $p < 0.05$), as can be seen in Figure 4, suggesting that very high temperatures have an adverse effect on corn production. This may indicate that, under moderate aridity conditions, wheat benefits from higher temperatures, either through a longer growing season or by optimizing physiological processes.
Precipitation also plays a crucial role in cereal production. Reduced rainfall can exacerbate the negative impact of elevated temperatures on corn, making drought-resistant hybrids essential. For wheat, moderate water stress may still be manageable, but prolonged droughts could limit its yield potential despite its higher adaptability to temperature variations.
Future agricultural planning should consider both temperature and precipitation patterns to develop sustainable crop management techniques, such as improved irrigation systems, drought-resistant crop varieties, and optimized sowing periods.
Drought events during key growth stages, such as flowering and grain filling, significantly hinder production, as illustrated in Figure 5. This outcome is anticipated, as corn has high moisture demands, and inadequate precipitation during the growing season can cause severe water stress, ultimately reducing yields. Beyond the total rainfall amount, its distribution throughout the growing season is also crucial, as shown in Figure 6. The strong positive correlation between annual precipitation and corn yields ($\rho = 0.57$, $p < 0.01$) underscores the crop's reliance on adequate water availability, as illustrated in Figure 7.
The impact of high temperatures is particularly severe for corn, which is highly sensitive to thermal stress, especially in the absence of irrigation. Similarly, barley and winter barley followed a pattern akin to wheat, displaying a higher tolerance to adverse climatic conditions and demonstrating their adaptability to heat extremes (Figure 8).
For wheat, the correlation was lower ($\rho = 0.06$, $p < 0.05$) but still significant, indicating a lower sensitivity to water deficit compared to corn.

This suggests that wheat is more resilient to variations in precipitation, likely due to its growth cycle and ability to utilize soil moisture more efficiently. However, prolonged drought conditions or extreme weather events could still impact its yield, albeit to a lesser extent than corn. The number of heatwave days exhibited a strong and significant negative correlation with corn production ($\rho = -0.77$, $p < 0.01$) as can be seen in Figure 9, highlighting the crops vulnerability to extreme temperatures. In contrast, wheat showed a negative but statistically insignificant correlation ($\rho = -0.32$, $p > 0.05$), suggesting greater resilience to heat stress.

Table 3. Average yields of grain cereals recorded in the period 2000-2023 (kilograms per hectare)

Year	CROP						
	Wheat	Maize	Barley	Oats	Rye	Triticale	Sorghum
2000	1327	1645	959	611	1875	-	-
2001	1918	1547	1875	1843	1000	-	-
2002	2119	2512	2196	1210	1352	-	-
2003	487	323	587	723	958	-	-
2004	3086	5853	-	1896	1500	-	-
2005	2654	3748	1985	1348	537	-	-
2006	2605	2803	2085	1236	1436	-	-
2007	859	727	977	268	700	-	-
2008	3030	3087	1842	1329	4900	-	-
2009	1350	3247	2108	1019	1026	-	-
2010	2428	3549	2820	1210	1484	-	-
2011	3404	4057	3497	1708	2153	-	-
2012	1226	1319	1084	970	1102	-	-
2013	2987	4430	2893	1390	1761	-	-
2014	3658	4689	3552	1844	2209	-	-
2015	3719	3067	3378	1666	3112	3435	-
2016	4065	3232	3617	2001	2410	3625	-
2017	4706	6345	4231	2130	2904	3270	-
2018	4588	8820	3975	2163	5365	2734	-
2019	4090	3573	3409	2074	3041	1559	-
2020	1581	1296	1585	1009	2202	791	340
2021	4738	4120	4121	2454	3948	3925	3800
2022	3213	2782	3076	2230	1358	2323	1200
2023	2988	2083	2680	1528	2409	1445	1100

Source: National Institute of Statistics, Romania. County Directorate for Agriculture – Tulcea (2023). *Statistical Data (1994–2023).*

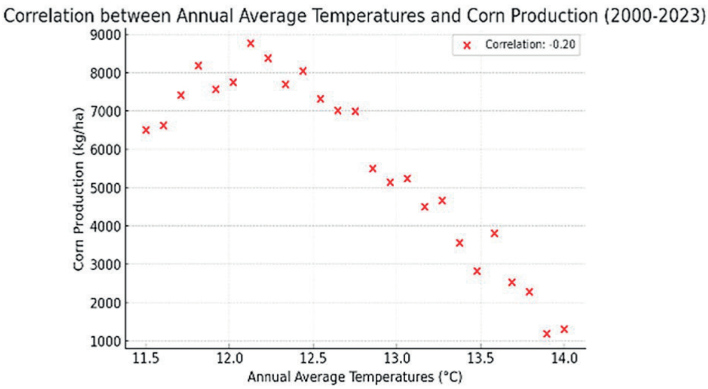

Figure 4. Correlation between annual average temperatures and corn yields from 2000 to 2023

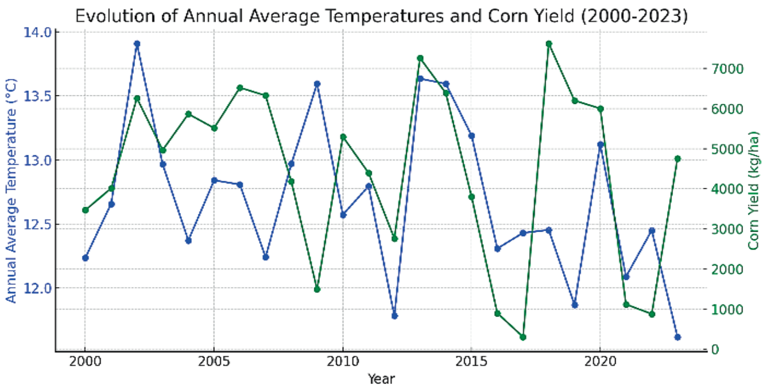

Figure 5. Evolution of annual average temperatures and corn yield from 2000 to 2023

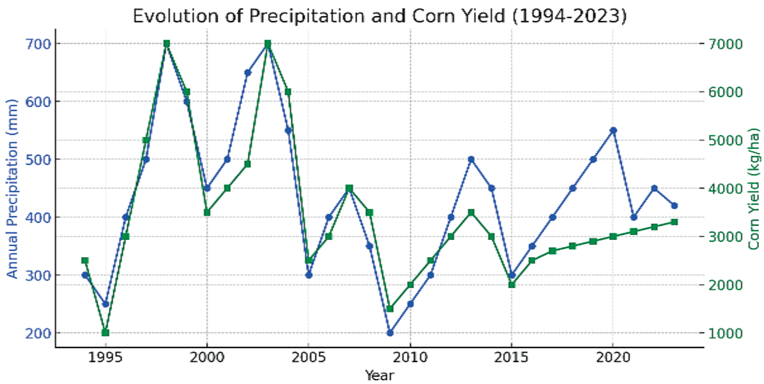

Figure 6. Evolution of average annual precipitation and corn production between 1994-2023

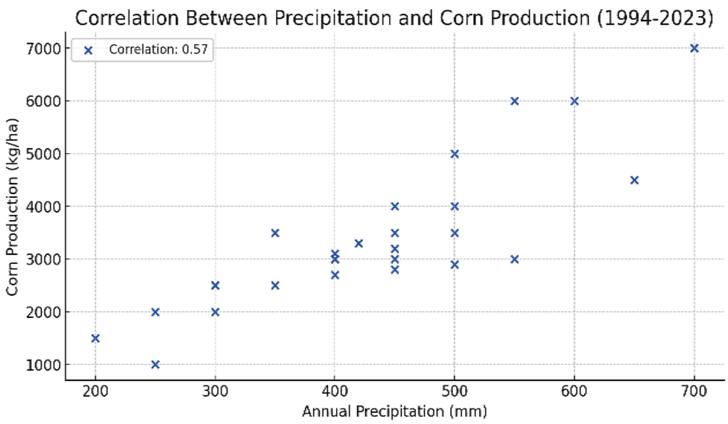

Figure 7. Correlation between average annual precipitation and corn production between 1994-2023

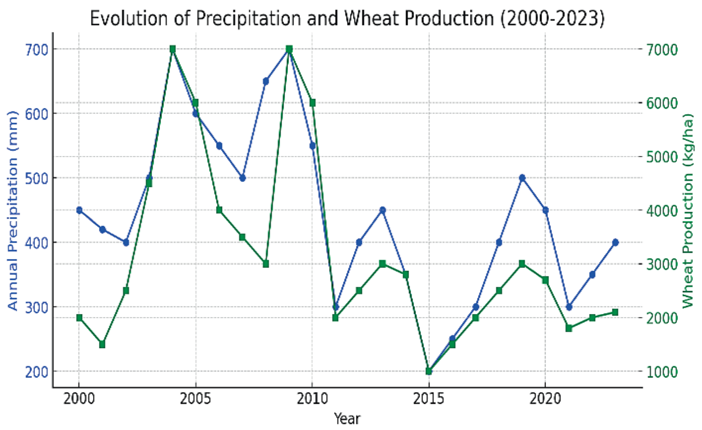

Figure 8. Evolution of average annual precipitation and wheat production Between 2000-2023

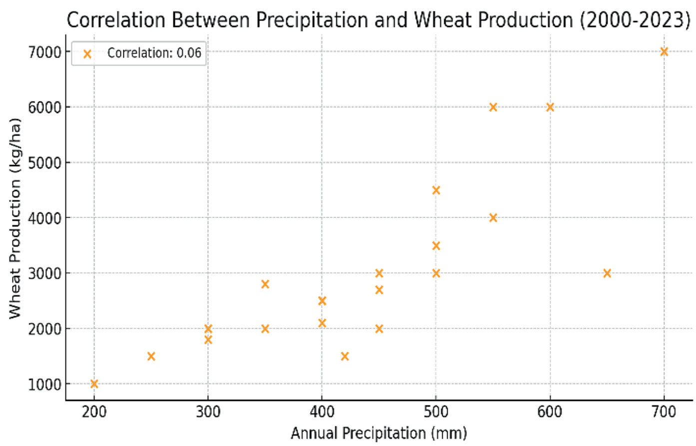

Figure 9. Corelation between average annual precipitation and wheat production between 2000-2023

CONCLUSIONS

The analysis of climate and agricultural data from 1994 to 2023 highlights a significant increase in average annual temperatures and a decline in precipitation, confirming global climate change trends. Average annual temperatures rose from approximately 10.49°C in the 1990s to 13.8°C in 2023, leading to intensified drought conditions and heat stress for crops. Annual precipitation dropped below the multiannual average of 488.79 mm, with considerable fluctuations from year to year. This uneven distribution of precipitation has negatively impacted crop development, particularly corn, which is highly sensitive to water deficits.

The area cultivated with grain cereals has been significantly influenced by climate conditions. In drought years with high temperatures, cultivated areas declined considerably, reaching a minimum of 118,948 ha in 2007. Due to its greater drought resistance, wheat occupied larger areas than corn during years with challenging climate conditions.

Agricultural yields reflect a partial adaptation to climate conditions, with significant fluctuations in productivity. Favorable years, such as 2018, allowed for maximum production levels (corn: 8,820 kg/ha, wheat: 4,738 kg/ha). In contrast, years with high temperatures and insufficient rainfall, such as 2003 and 2007, resulted in the lowest yields, emphasizing the vulnerability of crops to climate change.

The introduction of sorghum and triticale**,** crops more resistant to heat and water stress, represents a positive adaptation to the new climate conditions. However, their expansion remains limited, requiring greater promotion and support.

The findings suggest a complex relationship between climate variables and agricultural performance. Rising temperatures and decreasing precipitation pose major challenges for agriculture, leading to reduced productivity and changes in crop structure. Recent adaptations, such as the expansion of drought-resistant crops (sorghum, triticale), are essential strategies to ensure the sustainability of agriculture in Tulcea County.

The study highlights the necessity of implementing agricultural policies focused on expanding irrigation systems and modernizing existing infrastructure to mitigate water shortages during drought periods.

Key recommendations involve promoting efficient irrigation technologies, such as drip irrigation, to enhance water efficiency and strengthen agricultural resilience. Investing in research to develop wheat, corn, and other cereal varieties with increased tolerance to climatic stress.

Encouraging farmers to adopt alternative crops, such as sorghum and triticale, to reduce risks associated with extreme weather conditions.

Reducing dependence on monocultures by introducing a diversified range of crops, capable of buffering the impact of climate variability.

Organizing training programs for farmers on sustainable agricultural practices, efficient resource management, and adaptation to changing climate conditions.

Integrating climate adaptation strategies into national and regional agricultural development policies to ensure long-term resilience.

These conclusions and recommendations emphasize the importance of climate adaptation in securing the sustainability of agricultural production in Tulcea County. By implementing these measures, the vulnerability of local agriculture can be reduced, fostering the conditions for sustainable agricultural development.

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