Research Journal of Agricultural Science, 57 (4), 2025; ISSN: 2668-926X;

http://doi.org/10.59463/RJAS.2025.4.14

CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURAL PRODUCTIVITY IN TIMIȘ COUNTY

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Abstract: *Climate change poses significant challenges to agriculture worldwide, and the Timiş region in western Romania is no exception. Rising temperatures, irregular precipitation patterns, and increased frequency of droughts have already begun to affect crop growth, yields, and overall agricultural productivity in the area. Maize, wheat, sunflower, and other key crops are particularly vulnerable to heat stress and water scarcity, leading to potential reductions in harvests if adaptation measures are not implemented. This study reviews the observed and projected impacts of climate change on agriculture in Timiş County, analyzes future climate trends and highlights strategies for adaptation, including sustainable farming practices, crop diversification, and improved irrigation management. The findings underscore the urgent need for both local and regional policies to strengthen agricultural resilience and ensure food security in the face of ongoing climatic shifts. The analysis of ERA5-Land climatic parameters and agricultural yield data for 1990–2024 revealed moderate to strong correlations between temperature and crop productivity, confirming the regional warming trend's dual impact on yield stability and crop adaptation. Despite rising annual mean temperatures and lower annual precipitation totals, yields increased over the last two decades, reflecting technology-driven adaptation—improved genetics, fertilization, mechanization, and better timing of field operations—which mitigated climatic constraints and raised productivity.*

Key words: *climate change, agriculture, crop yield, Timiş County, adaptation strategies*

INTRODUCTION

Agriculture is one of the most climate-sensitive sectors, as temperature, precipitation, and extreme weather events directly affect crop growth and productivity. The Timiș region, located in western Romania, represents one of the country's most important agricultural zones, characterized by fertile soils and a continental-temperate climate that supports the cultivation of wheat, maize, sunflower, potatoes, and vineyards. These crops are essential for both local livelihoods and national food security (POPOVICI et al., 2015).

Over the past decades, climate change has become increasingly evident in Romania, particularly in the western and southern regions. Studies have shown a rise in average annual temperatures by 0.5–1.0 °C and more irregular precipitation patterns, with longer periods of drought followed by short, intense rainfall events (CROITORU et al., 2013; BĂLTEANU et al., 2020). These changes have intensified water stress, reduced soil moisture, and increased the frequency of extreme climatic events such as heatwaves, all of which negatively affect agricultural production (MATEESCU & ALEXANDRU, 2010).

The Timiş region, located in western Romania, is part of the historical Banat area and represents one of the country's most important agricultural zones. It covers an area of approximately 8,696 km² and has a population of around 700,000 inhabitants (INS, 2023). The region is characterized by fertile plains, gently rolling hills, and a temperate continental climate, which together create favorable conditions for diverse agricultural activities (POPOVICI & SĂVULESCU, 2015).

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The climate in Timiș is temperate-continental, with hot summers and cold winters. Average annual temperatures range between 10°C and 11°C, while annual precipitation varies from 500 to 800 mm, most of which falls during spring and early summer (Croitoru et al., 2013). However, in recent decades, the region has experienced increasing temperatures, irregular rainfall patterns, and more frequent extreme events, such as droughts and heatwaves, which have significantly affected crop productivity (MATEESCU & ALEXANDRU, 2010; BĂLTEANU et al., 2020).

The warming trend observed in Timișoara aligns with national and European climate analyses. According to BUSUIOC et al. (2021) and CROITORU et al. (2013), Romania’s mean annual temperature has increased by about 1.5°C over the last five decades, with the Banat Plain—where Timişoara is located—among the most affected regions. The frequency of hot days (>35°C) and tropical nights (>20°C) have risen significantly, while the duration of the frost season has shortened.

Soils in Timiș are among the most fertile in Romania, including chernozems, alluvial soils, and luvisols, which are well-suited for intensive and diversified agriculture (FLOREA & MUNTEANU, 2012). The region supports the cultivation of maize, sunflower, wheat, other cereals, potatoes, and vineyards for wine production. Maize and sunflower dominate the summer crops, wheat and cereals dominate winter crops, and vineyards are concentrated in the hilly zones of Recaș and Buziaș, where microclimatic conditions favor high-quality wine production (NEAȚĂ et al., 2021).

In the Timiș region, maize and sunflower are among the most affected crops due to their high sensitivity to heat and water deficit. Wheat remains relatively resilient but still experiences reduced yields during dry seasons (POPOVICI et al., 2015). Potato production is also influenced by rising temperatures, as it requires stable moisture conditions for optimal growth. Furthermore, vineyards face challenges related to water availability and changing phenological cycles, which influence grape quality and harvest timing (NEAȚĂ et al., 2021).

A significant minimum is observed around 2005, likely due to favorable rainfall conditions and better soil moisture availability in that period (MATEESCU & ALEXANDRU, 2010). After 2007, the data show a steady upward trend, indicating a worsening pattern of water deficit. This rise correlates with the increase in mean annual temperature and the reduction of summer precipitation observed across western Romania (CROITORU et al., 2013; BĂLTEANU et al., 2020).

The peak values recorded after 2015, reaching nearly 10,000–11,000 hectares, correspond to severe drought years such as 2015, 2018, and 2022, which were well-documented for their strong climatic anomalies (DUMITRESCU & BÎRSAN, 2015; BUSUIOC et al., 2021). These years were characterized by prolonged heatwaves and below-average precipitation, severely affecting maize, sunflower, and wheat production—the main crops of the Timiș agricultural zone.

Given these conditions, there is an urgent need to assess the relationship between climate variability and agricultural production in the Timiș region. This study aims to analyze the evolution of agricultural areas and crop yields from 1990 to 2024 in correlation with temperature and precipitation data, to better understand how climate change influences agricultural performance and to identify potential adaptation measures for local farmers.

MATERIAL AND METHODS

The study focused on Timiş County, located in western Romania, a region characterized by a continental temperate climate with strong interannual variability in temperature and precipitation. The analysis covered the 1990–2024 period, for which consistent climatic and agricultural data were available.

Climatic parameters

Climatic parameters were obtained from the ERA5-Land reanalysis dataset (Copernicus Climate Data Store), at a spatial resolution of 0.1° (~9 km). Three variables were selected as representative for agroclimatic conditions:

-total precipitation (prec_mm), annual sum (mm),

-2 m air temperature (t2m_c), annual mean (°C),

-evaporation from vegetation transpiration (etv_mm), annual sum in mm. (MUÑOZ-SABATER et al., 2021, HERSBACH et al., 2020).

All NetCDF files were imported into ArcGIS Pro 3.x using the *Make Multidimensional Raster Layer* tool, and processed as follows:

1. Temporal aggregation: monthly data were aggregated to annual values using the *Aggregate Multidimensional Raster* tool, with the *Yearly* interval keyword and *Mean* (for t2m_c, etv_mm) or *Sum* (for prec_mm) as aggregation methods.
2. Spatial extraction: annual rasters were clipped to the administrative boundaries of Timiș County.
3. Zonal statistics: for each variable, annual mean values within the county were extracted using the *Zonal Statistics as Table* tool, with the option „Process as multidimensional" enabled.

Climatological preprocessing. ERA5-Land monthly fields (0.1°; ~9 km) for total precipitation (tp, annual sum, mm), 2-m air temperature (t2m, annual mean, °C) and evaporation from vegetation transpiration (evavt, annual sum, m) were converted to annual indicators with *Aggregate Multidimensional Raster* and summarized spatially over Timiș County via *Zonal Statistics as Table* (area-weighted means). ERA5-Land surface fluxes are negative by convention; absolute annual sums were used for interpretability.

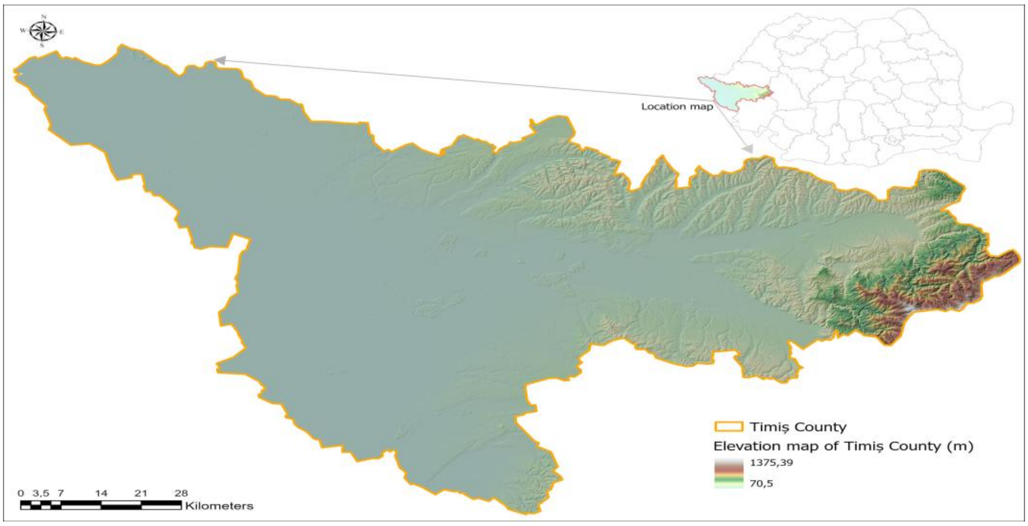

Figure 1. Timiș County, location and morphometric context supporting large-scale agriculture.

Agricultural production data

Research Journal of Agricultural Science, 57 (4), 2025; ISSN: 2668-926X;

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Agricultural yield data were obtained from the National Institute of Statistics (INS) for the same period (1990–2024), including the main crops cultivated in Timiș County: wheat, maize, sunflower, rapeseed, soybean, and grapes. The dataset provided annual yields in kg/ha, which were converted to t/ha for consistency.

Statistical analysis

The climatic and yield datasets were merged by year, resulting in a combined time series for each crop. For each variable pair (e.g., *wheat yield vs precipitation*), Pearson correlation coefficients were calculated to quantify the relationships between crop productivity and climatic variability. Scatter plots with linear trendlines were generated to visualize the relationships, and multi-parameter time series charts were created to compare yield fluctuations with interannual changes in precipitation, temperature, and evapotranspiration.

Statistical analysis was conducted in Microsoft Excel and ArcGIS Pro 3.x. Annual mean values for each climatic variable were correlated with corresponding annual crop yields using the Pearson correlation coefficient (r). The strength of the relationship was classified as weak ($|r| < 0.3$), moderate ($0.3 \leq |r| < 0.6$), or strong ($|r| \geq 0.6$).

RESULTS AND DISCUSSIONS

a. Evolution of Crop Yields in Timiș County (1990–2024)

General trends

The agricultural productivity in Timiș County has shown substantial interannual variability during the period 1990–2024, influenced both by technological progress and by climatic fluctuations specific to the western Romanian Plain. Overall, a long-term upward trend can be observed for all major crops, although significant yield reductions were recorded in several drought-affected years (especially 2000, 2007, 2012, and 2022). The general improvement after 2005 reflects the modernization of agricultural practices, increased mechanization, and the adoption of improved crop varieties tolerant to heat and water stress.

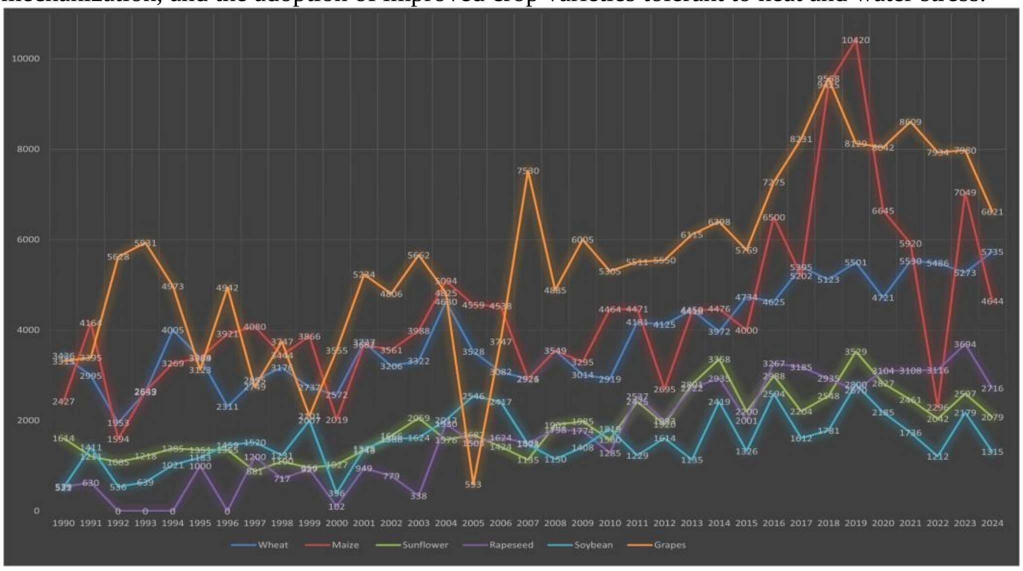

Figure 2. Annual crop yields kg/ha in Timiș County (1990–2024)

Between 1990 and 1993, there was a sharp decline in most crops, notably cereals, maize, and wheat. This decrease can be attributed to the post-communist agricultural restructuring period, during which land ownership changes and reduced investments temporarily lowered productivity (GHERGHINA & SIMIONESCU, 2015). From the mid-1990s to early 2000s, the cultivated areas and production levels gradually recovered as new farming systems and improved technologies were adopted.

Cereals and maize display moderate but fluctuating trends, with notable decreases during dry years such as 2003, 2012, and 2022 — years that correspond to severe drought events recorded in western Romania (BĂLTEANU et al., 2020; CROITORU et al., 2013). These fluctuations highlight the sensitivity of cereal crops to water deficits and temperature extremes.

In contrast, sunflower and rapeseed show an upward trend, especially after 2005. This shift reflects a progressive adaptation strategy toward drought-tolerant and economically profitable crops better suited to the changing climate (NEAȚĂ et al., 2021). Their expansion is also supported by EU agricultural policies and increased demand for biofuels and vegetable oils (POPESCU, 2020).

Wheat remains stable but exhibits slight improvement in the last decade, likely due to technological advancements (improved varieties, fertilization, mechanization) that have partially mitigated the effects of climatic stress (MATEESCU et al., 2015).

Overall, the results illustrate a gradual transformation of the cropping pattern in Timiș, driven by both climate change and market dynamics. The data suggest that farmers are increasingly favoring heat- and drought-tolerant crops, while more water-demanding species have either stagnated or declined. This evolution confirms the direct impact of rising temperatures and irregular precipitation on crop selection and agricultural sustainability in the region (BĂLTEANU et al., 2020; MATEESCU & ALEXANDRU, 2010).

Wheat (*Triticum aestivum*)

Average yields increased from approximately 3.0 t/ha in the 1990s to 5.0–5.5 t/ha in recent years, with a maximum of 5.73 t/ha in 2024. The sharp rise after 2005 indicates the transition to more intensive systems and the gradual stabilization of autumn–winter rainfall regimes. Low yields were recorded in 1992, 1996, and 2000, years marked by below-average precipitation. Conversely, the period 2014–2020 corresponds to a sequence of favorable years with high productivity, coinciding with wetter growing seasons and milder spring temperatures.

Maize (*Zea mays*)

Maize shows the largest amplitude of interannual variation, ranging from 1.6 t/ha (1992) to over 10.4 t/ha (2019). Yield growth is highly correlated with precipitation availability during the summer months, as well as with irrigation infrastructure improvements. The 2010s stand out as a decade of exceptionally high productivity, supported by favorable climatic conditions and improved hybrids. Severe reductions occurred in 2000, 2007, and 2022, all of which were characterized by extreme heat and prolonged drought episodes.

Sunflower (*Helianthus annuus*)

Sunflower yields exhibit a steady increase, from ~1.2 t/ha in the early 1990s to around 2.7–3.0 t/ha in the last decade. The upward trajectory is consistent with the expansion of drought-tolerant cultivars and optimized fertilization. Productivity peaks were observed in 2014, 2018, and 2021, corresponding to years with moderate temperatures and adequate soil moisture during flowering. However, yield reductions were notable in 1997, 1999 apparently unrelated to climatic conditions.

Rapeseed (*Brassica napus*)

Rapeseed was cultivated irregularly during the 1990s, with some years (1992-1994, 1996) showing zero production. After 2000, it became a stable crop, with yields rising to 3.2 t/ha in 2024. High interannual variability suggests strong dependence on winter survival and early spring precipitation. Exceptional yields in 2016–2023 reflect favorable agroclimatic conditions, while low yields in 2003 and 2007 coincide with dry winters and early heat stress.

Table 1.

Annual crop yields (kg/ha) in Timiş County and county-mean climate indicators from ERA5-Land

	wheat	maize	sunflower	rapeseed	soybean	grapes	precipitation[1]	temperature [2]	evapotranspiration [3]
1990	3436	2427	1614	539	521	3315	613.40	11.77	1.68
1991	2995	4164	1211	630	1411	3395	727.07	10.49	1.51
1992	1953	1594	1085	0	536	5628	664.08	11.80	1.78
1993	2633	2649	1218	0	639	5931	656.93	10.88	1.66
1994	4005	3269	1385	0	1021	4973	593.91	12.48	1.81
1995	3389	3384	1351	1000	1183	3123	846.39	11.12	1.71
1996	2311	3921	1355	0	1459	4942	844.40	10.45	1.56
1997	2895	4080	881	1200	1520	2749	824.77	10.39	1.55
1998	3176	3444	1100	717	1231	3747	663.80	11.16	1.70
1999	2737	3866	956	927	2007	2101	971.99	11.41	1.56
2000	2572	2019	1027	102	396	3555	485.06	12.65	1.90
2001	3737	3682	1343	949	1378	5234	941.22	11.45	1.73
2002	3206	3561	1666	779	1588	4806	689.91	12.42	1.72
2003	3322	3988	2059	338	1624	5662	597.27	11.41	1.77
2004	4630	5094	1576	1930	2012	4825	894.17	11.20	1.68
2005	3528	4559	1687	1503	2546	593	1036.12	10.37	1.53
2006	3082	4538	1424	1624	2417	3747	790.17	11.46	1.61
2007	2921	2926	1135	1501	1478	7530	797.99	12.50	1.86
2008	3549	3549	1902	1798	1150	4885	692.24	12.41	1.81
2009	3014	3295	1985	1774	1408	6005	819.79	12.41	1.78
2010	2919	4464	1580	1285	1819	5305	998.32	11.53	1.63
2011	4181	4471	2425	2537	1229	5511	508.75	11.55	1.77
2012	4125	2695	1920	1993	1614	5550	675.58	12.21	1.85
2013	4450	4418	2801	2722	1135	6115	827.12	12.36	1.73
2014	3972	4476	3358	2935	2419	6398	911.48	12.74	1.65
2015	4734	4000	2200	2001	1326	5769	640.99	12.74	1.77
2016	4625	6500	2988	3267	2594	7275	920.65	12.00	1.76
2017	5395	5202	2204	3185	1612	8231	576.31	12.28	1.79
2018	5123	9425	2548	2935	1781	9568	747.46	12.91	1.79
2019	5501	10420	3529	2670	2800	8129	679.58	13.11	1.80
2020	4721	6645	2827	3104	2185	8042	788.65	12.44	1.77

2021	5530	5920	2461	3108	1736	8609	762.58	11.93	1.84
2022	5486	2296	2042	3116	1212	7934	497.54	12.71	1.59
2023	5273	7049	2597	3694	2179	7980	449.62	13.11	0.95
2024	5735	4644	2079	2716	1315	6621	551.42	14.04	2.00

**Dark colors represent low yields per hectare, low precipitation,*
[1]: precipitation (mm/yr),
[2]: 2-m air temperature (°C),
[3]: evaporation from vegetation transpiration (mm/yr).

Soybean (*Glycine max*)

Soybean yields doubled over the study period, increasing from ~1.0 t/ha in the 1990s to 2.2–2.8 t/ha after 2015. The improvement reflects the introduction of genetically improved cultivars and the crop's growing adaptation to local conditions. The years 2014–2020 recorded consistent yields above 2.0 t/ha, while earlier periods, particularly 1992–2000, were marked by frequent declines associated with water stress.

Grapes (*Vitis vinifera*)

Viticultural productivity demonstrates a pronounced sensitivity to climatic variability. Average yields fluctuate between 3.0 and 8.0 t/ha, with the most productive period between 2010 and 2020, when yields often exceeded 8.0 t/ha. Conversely, yields declined sharply in 1997, 1999, and 2005, reflecting the combined effects of large amounts of precipitation. The overall rising trend after 2010 suggests better vineyard management and adaptation to changing climate conditions.

Grouping of production levels

For analytical purposes, the study period can be divided into three phases:

1. Low productivity phase (1990–2003) – marked by technological limitations, and transition after land reforms;
2. Moderate productivity phase (2004–2013) – characterized by gradual improvement in yields;
3. High productivity phase (2014–2024) – distinguished by record yields across all major crops, corresponding to improved agrotechnical practices and generally favorable hydrothermal regimes.

b. Climate–Yield Correlation Analysis

The Pearson correlation coefficients between annual crop yields and the main climatic variables (mean air temperature, annual precipitation, and evapotranspiration) reveal crop-specific sensitivities to interannual climatic variability in Timiș County for the 1990–2024 period (Table 2).

General trends

Temperature (t2m_c) exhibits the strongest and most consistent positive relationship with crop productivity, while precipitation and evapotranspiration show weaker or even inverse associations for grapes. This pattern indicates that temperature acts as a major determinant of crop phenology and potential yield formation, provided that soil moisture is not a limiting factor. Years with excessive evapotranspiration, deficient rainfall or uneven distribution of precipitation throughout the year are generally associated with yield reductions.

Wheat (*Triticum aestivum*)

Wheat yield correlates positively with mean annual temperature (r = 0.61), suggesting that slightly warmer conditions—particularly during early spring and grain filling—enhance productivity. The weak negative correlation with precipitation (r = −0.28) and the near-zero relationship with evapotranspiration (r = 0.07) indicate that excess rainfall may hinder productivity through waterlogging or delayed sowing. These results support the idea that moderate warming, combined with stable soil moisture, favors winter cereals in continental regions.

Maize (*Zea mays*)

For maize, correlations are relatively weak across all climatic variables, with r = 0.29 for temperature, r = 0.11 for precipitation, and r = −0.12 for evapotranspiration. This suggests that yield variability is driven by a complex combination of factors, including hybrid selection, soil fertility, and timing of rainfall events rather than annual totals alone. The slight positive response to temperature aligns with the crop's thermophilic nature, but excessive heat coupled with high evapotranspiration during pollination may limit yield potential. A seasonal (May–August) analysis would likely strengthen the signal.

Table 2.

Pearson correlations (r) between annual crop yields and climate variables in Timiș County (1990–2024)

crop	climate_var	pearson_r
Grapes	etv_mm	0.175076
Grapes	prec_mm	-0.312654
Grapes	t2m_c	0.6499839
Maize	etv_mm	-0.122378
Maize	prec_mm	0.1069123
Maize	t2m_c	0.2876636
Rapeseed	etv_mm	-0.08081
Rapeseed	prec_mm	-0.056499
Rapeseed	t2m_c	0.5433799
Soybean	etv_mm	-0.282268
Soybean	prec_mm	0.4682111
Soybean	t2m_c	0.0437709
Sunflower	etv_mm	0.0507665
Sunflower	prec_mm	-0.073008
Sunflower	t2m_c	0.5592774
Wheat	etv_mm	0.0710082
Wheat	prec_mm	-0.281536
Wheat	t2m_c	0.6067038

Sunflower (*Helianthus annuus*)

Sunflower yields show a moderate positive correlation with temperature (r = 0.56) and negligible relationships with precipitation (r = −0.07) or evapotranspiration (r = 0.05). This indicates a high adaptability to warm and moderately dry climates, consistent with its physiological tolerance to water deficit. The weak correlation with rainfall underscores the crop's deep rooting system and its capacity to exploit subsoil moisture under semi-arid conditions. The distribution of rain (not annual total) matters at flowering.

Rapeseed (*Brassica napus*)

For rapeseed, the relationship between yield and temperature is moderately positive (r = 0.54), while both precipitation and evapotranspiration are weakly negative (r = −0.06 and −0.08, respectively). These findings reflect the crop's vulnerability to winter freeze–thaw cycles and excessive soil moisture. Favorable thermal conditions in late winter and early spring likely enhance flowering success and pod development. The distribution of rain (not annual total) matters at winter survival.

Soybean (*Glycine max*)

Soybean yield exhibits a moderate positive correlation with precipitation (r = 0.47) and a negative correlation with evapotranspiration (r = −0.28). This confirms the crop's high dependence on adequate soil water supply during the vegetative and reproductive stages. The very weak correlation with temperature (r = 0.04) suggests that thermal variability within the studied range does not significantly constrain soybean productivity compared to water availability. Soybean behaves as a water-limited crop, with yields increasing in wetter years (r(precipitation) ≈ +0.47) and declining as atmospheric water demand rises (r(evapotranspiration) ≈ −0.28), underscoring the need to manage seasonal water deficits through soil moisture conservation and, where feasible, supplemental irrigation.

Grapes (*Vitis vinifera*)

Grapevine productivity shows a strong positive correlation with temperature (r = 0.65) and a moderate negative relationship with precipitation (r = −0.31). Warmer conditions tend to improve fruit ripening and sugar accumulation, while excess rainfall can lead to fungal diseases and dilution of grape quality. The weak positive correlation with evapotranspiration (r = 0.17) indicates that moderate water stress is not detrimental and may even enhance quality and yield. We note that extreme heat events (and water stress) still depress yields despite the mean-warming benefit. Rainy years can lead to the establishment of diseases, so what is important is not the annual amount of precipitation but the temporal dispersion. The positive and relatively strong association with mean air temperature (r > 0.60) points to a "moderate-warming benefit"; however, this advantage is frequently offset by extreme events—multi-day heat during flowering/ripening and poorly timed rainfall near harvest—so a focused analysis of the last decade, resolving event timing, is essential to capture the true yield sensitivity.

CONCLUSIONS

The combined analysis of climatic and agricultural datasets for Timiș County over 1990–2024 highlights clear evidence of climate-driven impacts on crop productivity. Temperature emerges as the dominant climatic factor influencing yield dynamics, showing moderate to strong positive correlations for most crops, particularly wheat, sunflower, and grapevine. In contrast, precipitation and evapotranspiration exhibit weaker or inconsistent relationships, emphasizing that yield responses are shaped by complex hydrothermal interactions. Despite the apparent benefits of moderate warming for thermophilic crops, the increasing frequency of extreme events such as droughts poses significant challenges to yield stability. The findings underline that climatic factors alone cannot explain agricultural performance; technological advancement, soil fertility, and farm management practices remain equally important.

Future adaptation efforts should focus on improving irrigation efficiency, developing drought-resistant cultivars, and implementing integrated climate-smart farming systems. Such measures are essential to maintain high productivity and ensure the long-term sustainability of agriculture in western Romania under ongoing climate change.

It is important to note that climatic variables alone do not fully explain yield variability. Technological factors such as irrigation efficiency, fertilization regimes, improved cultivars, and soil management practices play a decisive role in shaping the observed trends. Socio-economic transitions, including land consolidation and EU agricultural policies after 2007, have also contributed to the productivity increase observed in the last decade. Therefore, climate–yield relationships should be interpreted within a broader framework that integrates both environmental and management factors. However, a more detailed analysis covering the last decade, focused on the occurrence and timing of specific climatic extremes—such as late spring frosts, rainfall deficits during critical phenological stages, or prolonged periods of extreme heat—would likely reveal stronger and more direct correlations with yield variability. Such a refined approach would better capture short-term climate–yield interactions and support more targeted adaptation strategies for the agricultural sector.

BIBLIOGRAPHY

BĂLTEANU, D., DUMITRESCU, A., & SIMA, M. (2020). Climate change impact on agriculture in Romania: Trends and adaptation options. Romanian Journal of Geography, 64(2), 97–112.

BUSUIOC, A., CAIAN, M., BOJARIU, R., & BÎRSAN, M.-V. (2021). Recent changes in temperature and precipitation extremes in Romania: Observed trends and future projections. Atmosphere, 12(3), 285.

CROITORU, A.-E., PITICAR, A., DRAGOTĂ, C.-S., & BURADA, D. C. (2013). Changes in temperature and precipitation extremes in Romania (1951–2010). Theoretical and Applied Climatology, 111(1–2), 167–177.

DUMITRESCU, A., & BÎRSAN, M.-V. (2015). Trends in precipitation extremes over Romania (1961–2013). Natural Hazards and Earth System Sciences, 15(1), 1–14.

FLOREA, N., & MUNTEANU, I. (2012). Romanian System of Soil Taxonomy (SRTS). Editura Sitech, Craiova.

GHERGHINA, R., & SIMIONESCU, M. (2015). Post-communist transformation of the agricultural sector in Romania. Procedia Economics and Finance, 22, 124–130.

HERSBACH, H., BELL, B., BERRISFORD, P., HIRAHARA, S., HORÁNYI, A., MUÑOZ-SABATER, J., SIMMONS, A. (2020). *The ERA5 global reanalysis.* Quarterly Journal of the Royal Meteorological Society, 146(730), 1999–2049. https://doi.org/10.1002/qj.3803 rmets.onlinelibrary.wiley.com

MATEESCU, E., & ALEXANDRU, D. (2010). Climate change impact on agriculture in Romania and adaptive measures. Journal of Environmental Protection and Ecology, 11(3), 931–939.

MUÑOZ-SABATER, J., DUTRA, E., AGUSTÍ-PANAREDA, A., ALBERGEL, C., ARDUINI, G., BALSAMO, G., ZSOTER, E. (2021). *ERA5-Land:* A state-of-the-art global reanalysis dataset for land applications. Earth System Science Data, 13, 4349–4383. https://doi.org/10.5194/essd-13-4349-2021 ESSD+1

NEAȚĂ, G., NICULAE, M., & ȚIBU, C. (2021). Climate change effects on viticulture in Romania. Scientific Papers Series B: Horticulture, 65(1), 57–64.

POPESCU, A. (2020). Trends in drought impact on Romanian agriculture and adaptation measures. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(3), 357–364.

POPOVICI, E. A., & SĂVULESCU, I. (2015). Climate change impacts on agricultural crops in the Timiș Plain, Romania. ResearchGate publication, available online.

Research Journal of Agricultural Science, 57 (4), 2025; ISSN: 2668-926X;

http://doi.org/10.59463/RJAS.2025.4.14

***Copernicus Climate Change Service (C3S) *ERA5-Land monthly averaged data from 1950 to present* [dataset]. Climate Data Store, European Centre for Medium-Range Weather Forecasts. Retrieved October 28, 2025, from the CDS portal. Climate Data Store

***European Environment Agency (EEA). (2021). EU-DEM v1.1 – Digital Elevation Model (25 m) [Data set]. Copernicus Land Monitoring Service.

***Eurostat GISCO. (2024). Administrative boundaries – NUTS 2024 (1:1 million, EPSG:4326) [Data set]. European Commission, Eurostat. Retrieved from https://gisco-services.ec.europa.eu/distribution/v2/nuts/

*****National Institute of Statistics (INS). (n.d.). *TEMPO-Online time series database.* Retrieved October 28, 2025.

***National Meteorological Administration (ANM Romania). (2023). *Climatological data and trends for Western Romania, 1990–2022*. Bucharest: ANM Reports.