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Climatic Drivers of Cereal Productivity in Romania (1997-2024): A Macro-Level Analysis Integrating ERA5 Precipitation Data and National Crop Statistics

Mihaela Pila and Silvius Stanciu

''Dunărea de Jos" University of Galaţi, Galaţi County, Romania
*Corresponding author. E-mail: Silvius.Stanciu@ugal.ro

ABSTRACT

A clear understanding of how climate variability influences cereal productivity is essential for developing resilient agricultural technologies and improving crop management practices. This study examines the impact of seasonal precipitation patterns on Romania's major cereal crops - wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.) - over a 28-year period (1997-2024). Monthly ERA5 reanalysis data were aggregated to obtain annual totals and season-specific precipitation windows relevant to crop phenology: April-June for wheat, June-August for maize and March-May for barley. These climatic datasets were integrated with national statistics on sown area, production and yield levels. The results indicate that precipitation remains a primary climatic driver of interannual yield variability, particularly for crops harvested in summer. Wheat shows a moderate and consistent positive association with spring rainfall ($R^2 \approx 0.48$), reflecting its sensitivity during stem elongation and grain filling. Maize displays higher climatic vulnerability, although the statistical association with summer rainfall remains relatively weak ($R^2 \approx 0.15$), highlighting the combined influence of water availability and thermal stress during pollination and early grain development. Barley shows weaker correlations ($R^2 \approx 0.01$), consistent with its earlier phenology and tolerance to early-season moisture fluctuations. At the national scale, the relationship between total annual precipitation and combined cereal output is weak ($R^2 \approx 0.22$), indicating compensatory effects among crops and the influence of technological progress in crop management, breeding and input use. Overall, the study provides a macro-level diagnostic framework for understanding the climatic drivers of cereal productivity in Romania. The findings emphasize the need for climate-adapted strategies such as drought-tolerant germplasm, improved sowing schedules and precision water management to enhance resilience under increasing climatic variability.

Keywords: precipitation, cereal productivity, ERA5, climate variability, Romania, wheat, maize, barley.

INTRODUCTION

Cereals represent the foundation of Romania's agricultural production system, forming both the backbone of the agro-food sector and a central pillar of national food security. Over the past two decades, Romania has consistently ranked among the leading European producers of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.), owing to favourable pedoclimatic conditions, extensive arable land resources, and the gradual adoption of improved technologies (Eurostat, 2023; MADR, 2023). Despite these advances, cereal productivity remains strongly constrained by climatic variability, particularly by the distribution of seasonal precipitation, given that a large share of the agricultural area is still cultivated under rainfed conditions (Horhocea et al., 2024). Romania's temperate-continental climate is characterized by marked seasonal contrasts and high interannual atmospheric variability, resulting in uneven spatial and temporal distribution of water resources. The southern, eastern and south-eastern regions - key production areas for cereals - are frequently affected by soil moisture deficits, while the frequency and intensity of drought episodes have increased significantly in recent decades (Spinoni et al., 2017; ANM, 2021; Partal et al., 2021). The intensification of extreme climatic events, including heatwaves, extended dry spells and abrupt alternations between wet and dry periods, has direct implications for the critical growth stages of cereal crops, ultimately reducing yield stability. Globally, the relationships

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between climate variability and crop performance are well documented. Lobell et al. (2011) demonstrated that recent climatic trends have led to substantial yield reductions for major staples, particularly in drought-prone regions. Long-term assessments by Ray et al. (2015) showed that approximately one-third of interannual yield variability worldwide can be attributed to climatic factors, especially precipitation and temperature extremes. At the European level, studies by Trnka et al. (2014) and reports by FAO (2022) highlight that southern and eastern areas of the continent are among the most exposed to yield losses caused by water stress and increasing evapotranspiration.

In Romania, the link between precipitation patterns and cereal productivity aligns with global findings. Mateescu and Alexandru (2016) demonstrated that spring moisture deficits significantly reduce wheat yields, particularly in southern regions characterized by soils with low water-holding capacity. Research conducted in the Romanian Plain by Sima et al. (2015a) revealed severe impacts of atmospheric and soil drought on maize production, especially during pollination and grain filling.

Evidence from Romanian agro-climatic studies confirms strong linkages between climatic variability (particularly water deficit during summer) and crop responses, with farmer-level analyses indicating significant stress effects on cereal yields (Mitrică et al., 2015; Sima et al., 2015b).

Additional studies from Transylvania and Moldova have shown consistent dependency of cereal yields on precipitation supply, particularly in April-June and June-August (Boian and Brezeanu, 2021). European assessments indicate that Romanian agriculture is among the most vulnerable to seasonal water deficits in Central-Eastern Europe, largely due to extensive non-irrigated farming and the degradation of hydro-technical infrastructure following 1990 (Trnka et al., 2014; EEA, 2023). A comprehensive national study by Simota and Dumitru (2014) estimated that yield losses during severe drought years can reach 30-60% and may exceed 70% in extreme cases such as 2007 and 2012. Indicators such as SPEI confirm a direct link between drought severity and reduced wheat and maize yields (Sima et al., 2015a). In this context of increasing climate vulnerability, irrigation emerges as a strategic adaptation measure. Irrigated areas in Romania have decreased dramatically after 1990 - from over 3 million hectares to roughly 300,000 ha used annually (MADR, 2023) - increasing the dependency of crop yields on natural precipitation. Studies show that in dry years, irrigated crops may achieve 40-70% higher yields compared to rainfed systems (Simota and Dumitru, 2014), while modern irrigation technologies enhance water-use efficiency and yield stability (Boian and Brezeanu, 2021). Overall, the literature demonstrates that precipitation continues to play a central role in shaping cereal productivity patterns in Romania. This dependency is amplified by regional pedoclimatic characteristics, the predominance of rainfed systems and the increasing irregularity of seasonal rainfall. By integrating ERA5 climate reanalysis data with long-term agricultural statistics, this study aims to provide a coherent macro-scale assessment of the climatic drivers shaping the performance of wheat, maize and barley in Romania over the period 1997-2024. The analysis contributes to a deeper understanding of how precipitation variability influences cereal output and supports the development of adaptive strategies for enhancing resilience under ongoing climatic change.

MATERIAL AND METHODS

Literature review

The literature review was conducted exclusively using open-access scientific articles, institutional databases, technical reports and official statistics. Publications were retrieved from major open scientific platforms (MDPI, Copernicus, Frontiers, PLOS, DOAJ, CORE), together with documents issued by international organisations such as FAO, EEA, Eurostat and IPCC. For the climatic component, ERA5 reanalysis datasets (Copernicus) and reports of the Romanian National Meteorological Administration (ANM) on extreme weather events were consulted. For the agricultural component, long-term national statistics from INS Tempo Online and annual crop reports published by the Ministry of Agriculture and Rural Development (MADR) represented the main source of data. This combination of validated, publicly accessible sources ensured a rigorous and reproducible methodological framework.

Climatic data

Climatic data used in this study were extracted from the ERA5 global reanalysis dataset provided by the Copernicus Climate Change Service. ERA5 is one of the most robust and widely validated climatic datasets, offering long-term, spatially homogeneous atmospheric variables at a spatial resolution of 0.25° (Hersbach et al., 2020). For the period 1997-2024, monthly precipitation totals were retrieved for the entire Romanian territory. National averages were computed using area-weighted aggregation to ensure consistent representation of annual and seasonal rainfall patterns across the country.

Seasonal precipitation windows

Seasonal precipitation windows were defined according to the crop phenology and agro-ecological requirements documented in the literature (FAO EcoCrop; Liu et al., 2013):

Wheat (*Triticum aestivum* L.): April-June; Critical stages: stem elongation, heading, flowering, early grain filling.

Maize (*Zea mays* L.): June-August; Critical stages: silking, pollination, grain filling; highest water demand.

Barley (*Hordeum vulgare* L.): March-May; Critical stages: tillering, stem elongation and spike initiation.

For each interval, total precipitation amounts were computed from ERA5 monthly values and used as explanatory climatic indicators in the statistical analysis.

Agricultural data

Agricultural data were obtained from official institutional sources. The INS Tempo Online database (1997-2024) provided consistent, long-term national statistics, complemented by annual MADR reports for verification and completion of missing entries. For wheat, maize and barley, the following variables were analysed: sown area (thousand ha); total production (tonnes)**;** average yield (kg/ha)**.** All datasets were checked for internal consistency. The few missing values identified were corrected using conservative interpolation techniques without altering long-term trends.

Analytical procedure

The relationship between precipitation patterns and crop performance was evaluated using Pearson correlation coefficients (r), following standard methodologies applied in agro-climatic research (Trnka et al., 2014; Ray et al., 2015). Analyses included: correlation between annual precipitation and total cereal production; correlation between crop-specific seasonal precipitation windows and agricultural indicators (production and yield) for each crop: wheat: April-June precipitation; maize: June-August precipitation; barley: March-May precipitation.

Scatter plots and linear regression trendlines were further used to illustrate the strength and direction of climatic relationships.

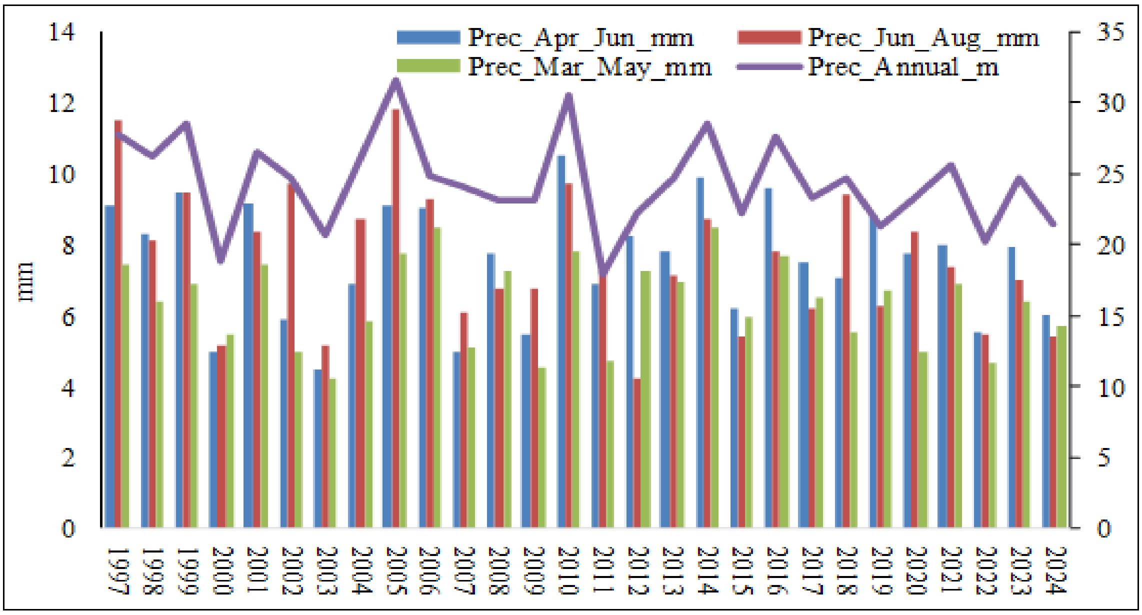
Use of artificial intelligence tools

Artificial intelligence tools were employed exclusively to support language verification, consistency checking between Romanian and English translations, and preliminary statistical validation. All scientific reasoning, data processing and interpretations were performed manually by the authors. The use of AI tools did not influence the originality, methodology or scientific content of the study.

RESULTS AND DISCUSSION

Evolution of precipitation amounts in Romania

The evolution of mean precipitation levels during the 1997-2024 period is presented in Figure 1.



Source: Authors' compilation based on ERA5 reanalysis data (Copernicus Climate Change Service) and national aggregation methods.

Figure 1. Average monthly and annual precipitation in Romania (1997–2024)

Monthly precipitation averages were extracted for the crop-specific seasonal windows relevant to wheat (April-June), maize (June-August), and barley (March-May), alongside annual mean values. These indicators were selected to reflect the climatic conditions during the critical phenological stages of each crop. An examination of the precipitation series reveals a pronounced interannual variability, both in the annual totals and in the seasonal windows corresponding to key crop development phases. Overall, the data indicate substantial short-term oscillations, yet without a clear long-term increasing or decreasing trend. This behaviour is typical for temperate-continental climates, where fluctuations between wet and dry years are frequent and strongly influence agricultural performance. Annual mean precipitation (Prec_Annual_mm) generally fluctuates between 18 and 30 mm (expressed as monthly means), with marked minima in 2000, 2007, 2011, 2020 and 2024 - years widely recognized in national climatological assessments as severely dry. In contrast, years such as 2005, 2010, 2014 and 2017 recorded significantly higher annual values, highlighting the inherently oscillatory nature of the climatic regime. Distinct patterns emerge when analysing crop-specific seasonal precipitation:

- April-June precipitation (Prec_Apr_Jun_mm - wheat)

Values show moderate variability, with notable minima in 2000, 2003, 2007 and 2024 - years also associated with reduced wheat yields. Higher levels in 2005, 2010 and 2014 correspond to favourable production years, confirming the crucial role of spring and early-summer moisture for *Triticum aestivum* L.

- June-August precipitation (Prec_Jun_Aug_mm - maize)

This interval displays the highest interannual variability among the seasonal windows. Marked reductions in 2000, 2007, 2011 and 2020 coincide with significant national yield losses in maize, reflecting the strong sensitivity of *Zea mays* L. to water stress during pollination and grain filling. Conversely, 2005, 2010 and 2018 stand out as years with favourable summer rainfall and above-average yields.

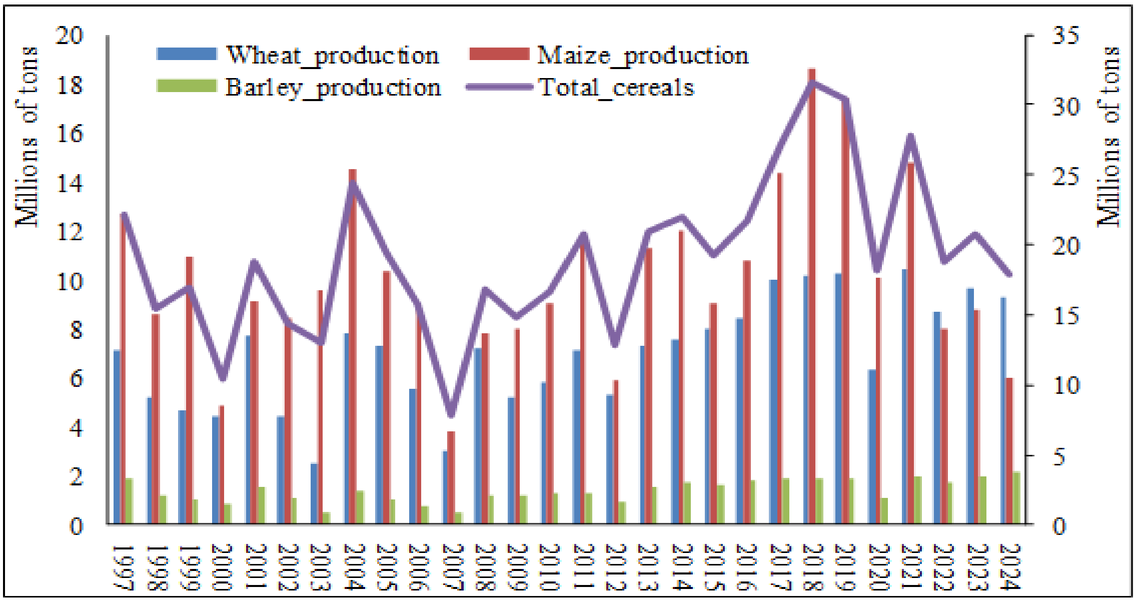
- March-May precipitation (Prec_Mar_May_mm - barley)

Variability is relatively lower compared to the other series, consistent with the earlier phenology and shorter vegetative cycle of *Hordeum vulgare* L. Even so, years such as 2002, 2003, 2007 and 2024 recorded precipitation deficits that negatively affected national barley output.

Across all series, summer precipitation (June-August) displays the greatest amplitude of variation, highlighting the intensification of extreme climatic events during the warm season. This observation aligns with recent European studies reporting an increased frequency of atmospheric droughts in Southeastern Europe.

In summary, Figure 1 demonstrates that precipitation distribution - particularly its seasonal timing rather than annual totals - remains the primary climatic factor influencing cereal production in Romania. The pronounced variability of rainfall during key phenological windows explains a substantial part of the fluctuations observed in annual cereal output during the study period.

The evolution of wheat, maize and barley production during the 1997-2024 period is presented in Figure 2. The analysis reveals a pronounced interannual variability in total output, largely driven by seasonal climatic fluctuations and by the predominantly rainfed character of Romania's agricultural sector. Although technological improvements, the adoption of high-performance cultivars and the modernization of farm practices have contributed to a general upward trend, production levels remain strongly constrained by water availability during critical phenological stages.



Source: Authors, based on INS Tempo Online (2025).

Figure 2. Cereal production in Romania (wheat, maize and barley), 1997-2024

Wheat (*Triticum aestivum* L.)

Wheat production shows a long-term increasing trend, with values ranging between 2.4 million tonnes (2003) and 10.4 million tonnes (2021). The major production minima recorded in 2000, 2003, 2007 and 2020 coincide with periods of severe water deficit in April-June, confirming the crop's high sensitivity to spring moisture shortages during stem elongation, heading and grain filling.

Production maxima in 2014, 2017 and 2021 coincided with years characterised by more favourable rainfall patterns and continued technological advancement across farms.

Maize (*Zea mays* L.)

Maize exhibits the highest year-to-year variability among the analysed crops, with production levels ranging from 3.8 million tonnes (2007) to 18.6 million tonnes (2018). Minimum values correspond to the drought-affected years 2000, 2007, 2012 and 2020, which were characterised by significantly below-average precipitation in June-August. The highest outputs, observed in 2014, 2017, 2018 and 2021, occurred in seasons with adequate summer rainfall and reduced frequency of heat waves. This pattern confirms the crop’s strong vulnerability to water stress during pollination and grain filling.

Barley (*Hordeum vulgare* L.)

Barley production fluctuated less compared to maize and wheat, ranging from 0.53 million tonnes (2007) to 2.2 million tonnes (2024). Minimum outputs correspond to early-spring water deficits (March-May), whereas maxima are associated with wetter springs and moderate temperatures. As a short-season crop, barley is primarily affected by early-spring hydrological conditions; the relatively lower interannual variability confirms these agronomic characteristics.

Total cereal production

Romania’s total cereal output (wheat + maize + barley + other cereals) shows a substantial increase compared to the late 1990s, reaching a peak of 31.5 million tonnes in 2018. However, sharp declines in 2007, 2012 and 2020 highlight a persistent vulnerability of the agricultural system to climatic variability. Production troughs correspond almost perfectly to years with below-average precipitation in key phenological windows, confirming the strong dependency of cereal yields on seasonal water availability.

Maize remains the most climate-sensitive crop, showing pronounced interannual fluctuations driven primarily by summer water stress.

Wheat displays a clear long-term upward trend, yet its productivity continues to depend heavily on adequate spring rainfall.

Barley exhibits comparatively lower variability, with yields influenced mainly by early-spring precipitation dynamics. Overall, total cereal production reflects both climatic variability and technological progress, but severe drought years (2000, 2007, 2012, 2020) continue to exert substantial negative impacts on national output.

Correlation analysis between precipitation and cereal production (1997-2024)

To evaluate the relationship between seasonal rainfall patterns and the performance of wheat, maize and barley, Pearson correlation coefficients were calculated between monthly mean precipitation values aggregated on crop-specific phenological windows and the corresponding agricultural indicators (total production and average yield).

The results reveal clear differences in crop sensitivity to hydric variability across seasons.

Correlation between April-June precipitation and wheat production

The relationship between wheat production and spring rainfall (April-June) is illustrated in Figure 3.

A moderate positive correlation is evident, indicating that higher precipitation levels during this phenologically critical period are generally associated with increased national wheat output.

Years marked by pronounced water deficits - such as 2000, 2003, 2007 and 2020 - align with significantly reduced production levels, confirming the high sensitivity of *Triticum aestivum* L. to moisture availability during stem elongation, heading and early grain filling.

The linear regression model ($R^2 = 0.4784$) shows that nearly half of the interannual variability in wheat production can be statistically explained by rainfall in this interval.

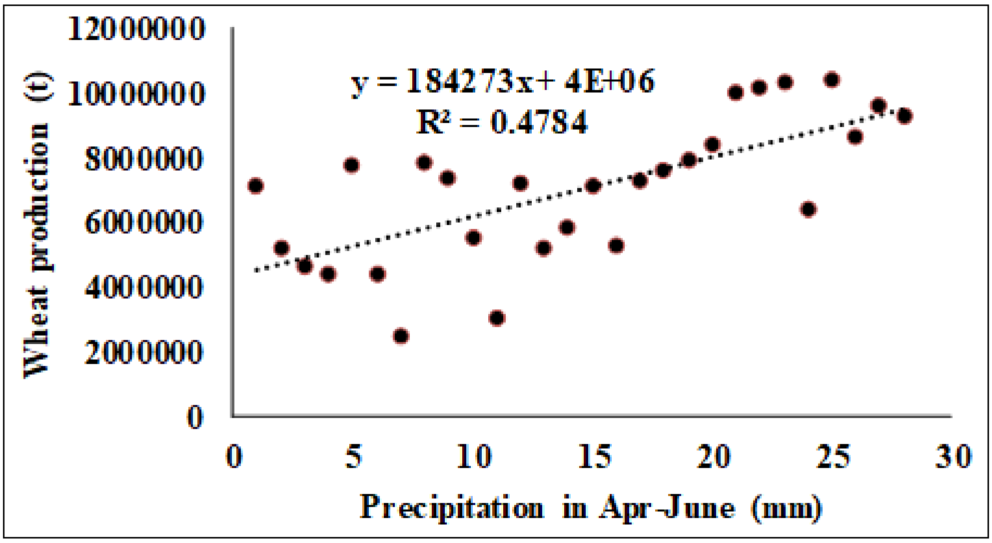


Figure 3. Relationship between April-June precipitation and wheat production in Romania during 1997-2024. The dotted line represents the linear regression trendline.

Although additional factors such as thermal stress, soil moisture reserves, cultivar characteristics and farm-level technological inputs also influence annual production, the analysis clearly demonstrates that seasonal precipitation remains the primary climatic determinant of wheat performance under predominantly rainfed conditions in Romania.

Maize production and June-August precipitation

The relationship between national maize production and summer precipitation is shown in Figure 4.

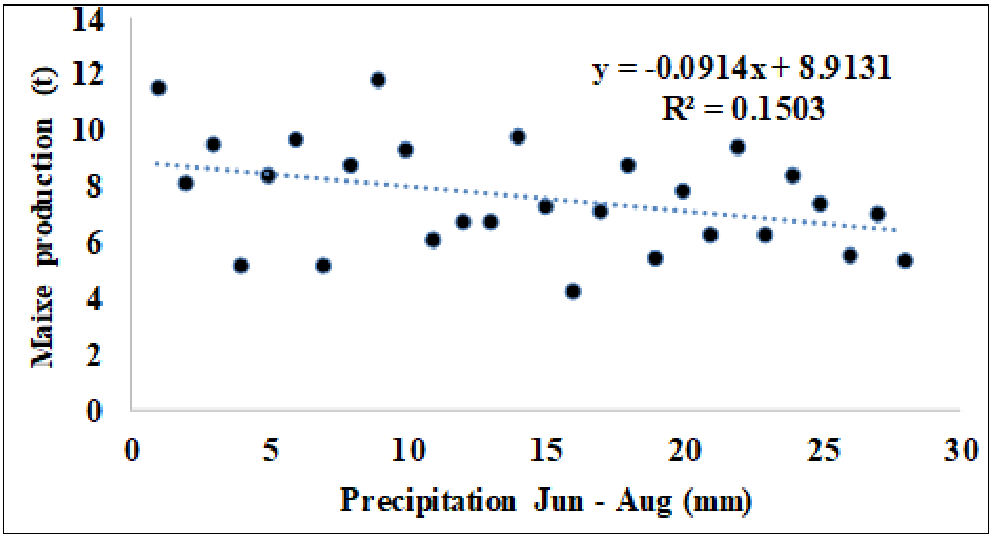


Figure 4. Scatter plot showing the relationship between June-August precipitation and national maize production. The dotted line represents the linear regression trendline.

Although the scatter distribution exhibits substantial interannual variability, the analysis reveals only a weak negative correlation between maize output and June-August precipitation (R^2 = 0.1503). This suggests that summer rainfall alone explains only a limited share of yield fluctuations. The weak association can be attributed to the increasing frequency of heat extremes, atmospheric drought, and enhanced evapotranspiration during the warm season, which may offset the positive effects of rainfall.

Years with relatively high summer precipitation do not consistently correspond to high production levels, indicating that under current climatic conditions, thermal stress exerts a stronger influence on maize performance than total summer rainfall. Conversely, the lowest production values - such as those recorded in 2000, 2007, 2012, and 2020 - occurred in years when severe moisture deficits overlapped with critical phenophases, particularly silking and grain filling. This pattern confirms the strong vulnerability of *Zea mays* L. to combined water and heat stress during the reproductive period.

Overall, the results indicate that while summer precipitation remains an important climatic driver, it is not the sole determinant of maize productivity. The intra-seasonal distribution of rainfall, duration of heatwaves, soil water-holding capacity, and timing of dry spells also play decisive roles in shaping annual maize yields in Romania.

Figure 5 illustrates the **relationship between March-May precipitation and national barley production**. The analysis reveals a very weak association between early-spring rainfall and annual output levels, as indicated by the extremely low coefficient of determination (R^2 = 0.0097). Although barley (*Hordeum vulgare* L.) is an autumn-sown crop that relies partly on soil moisture accumulated during winter and early spring, variability in March-May precipitation accounts for only a marginal share of production fluctuations at the national level.

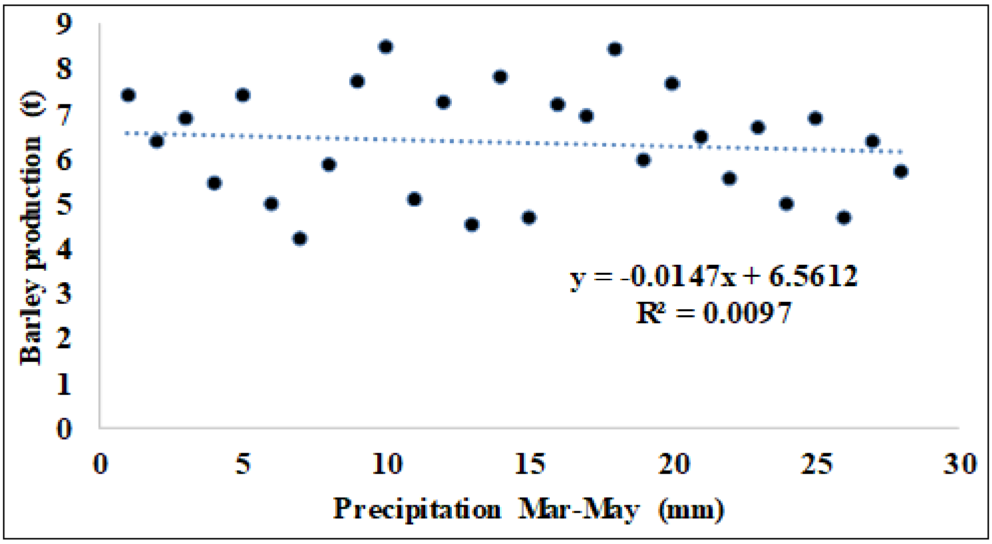


Figure 5. Relationship between March-May precipitation and barley production in Romania (1997-2024)

This limited sensitivity is largely attributable to barley's shorter growing cycle and its comparatively higher tolerance to early-season moisture variability relative to other small-grain cereals. Furthermore, barley yields are strongly influenced by technological factors, including crop density, fertilization regimes, and temperature conditions during tillering and stem elongation. As a result, spring precipitation represents only a secondary determinant of national yield variability for this crop.

Figure 6 illustrates the **relationship between annual precipitation totals and Romania's combined cereal** production over the 1997-2024 period.

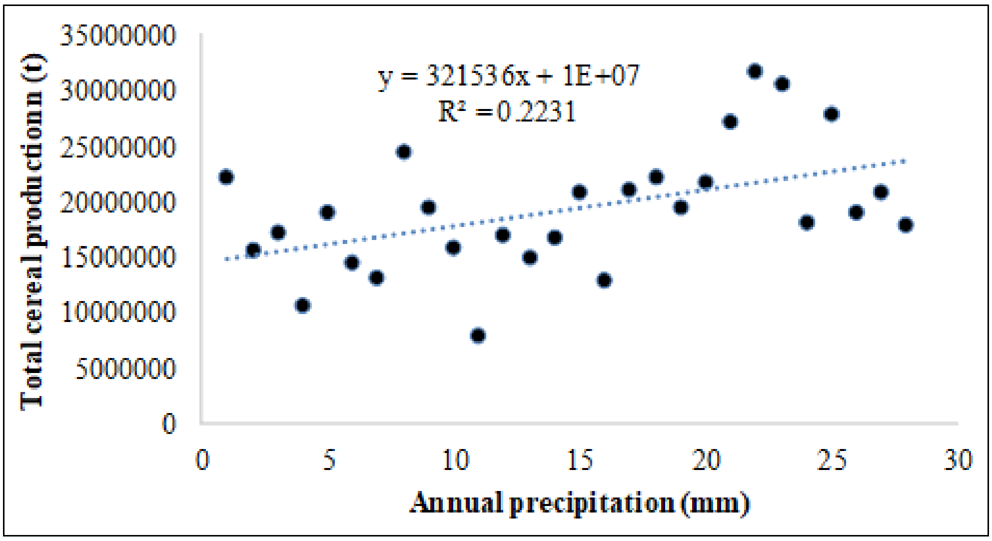


Figure 6. Relationship between annual precipitation and total cereal production in Romania (1997-2024)

The regression line indicates a moderate positive association between the two variables, suggesting that years with higher annual rainfall generally correspond to higher national cereal outputs. The coefficient of determination (R^2 = 0.2231) shows that approximately 22% of the interannual variability in total cereal production can be statistically explained by variations in annual precipitation - a substantial proportion considering the predominantly rainfed nature of Romanian agriculture.

Despite this moderate trend, the dispersion of points around the regression line highlights considerable variability, reflecting the strong influence of non-climatic factors such as cultivar characteristics, fertilization intensity, soil management practices and the occurrence of localized extreme weather events. Years marked by severe drought (2007, 2012, 2020) are positioned visibly at the lower end of the distribution, confirming the vulnerability of the cereal sector to hydric deficits. Conversely, years with above-average precipitation (2014, 2017-2018) align in the upper segment of the graph, coinciding with some of the highest national production levels recorded during the study period.

Overall, these findings reinforce the central role of annual precipitation in shaping Romania's total cereal output and underline the importance of adaptive measures to climate variability - particularly the expansion and modernization of irrigation systems and the implementation of improved water management strategies.

Pearson Correlation Analysis between Precipitation and Cereal Production (1997-2024)

The Pearson correlation coefficients calculated for the 1997-2024 period highlight distinct relationships between seasonal precipitation patterns and the performance of wheat, maize and barley. The results confirm trends widely reported in the agro-climatic literature, while also providing new insights into the specific vulnerabilities of Romanian cereal production to climate variability. Differences observed among crops reflect the timing of rainfall sensitivity within their phenological cycles, the influence of extreme temperatures, and the predominance of rainfed agriculture at national scale. Overall, the analysis demonstrates that precipitation constitutes an essential climatic driver of interannual production dynamics, but its impact is modulated by additional factors such as soil moisture reserves, thermal stress, agronomic management and technological improvements.

Table 1. Pearson correlation coefficients between precipitation indicators and cereal production in Romania (1997-2024)

Crop/ Indicator	Precipitation window	Pearson r	Interpretation
Wheat production	April-June precipitation	+0.69	Moderate-strong positive correlation; higher spring rainfall is associated with increased wheat output.
Maize production	June-August precipitation	–0.39	Weak negative correlation: summer rainfall alone does not explain yield variation due to high heat-stress sensitivity.
Barley production	March-May precipitation	+0.10	Very weak positive correlation: early-spring rainfall has limited influence on national barley output.
Total cereal production	Annual precipitation	+0.47	Moderate positive correlation: wetter years tend to show higher combined cereal output.

Source: Authors' calculations based on ERA5 and INS datasets.

For wheat (*Triticum aestivum* L.), the Pearson coefficient (r = 0.69) confirms a moderate-to-strong positive association with April–June precipitation, and the regression model further shows that nearly half of the interannual production variability is statistically explained by spring rainfall ($R^2 \approx 0.48$).

These findings are consistent with the results of Mateescu and Alexandru (2016), who demonstrated that spring moisture deficits directly reduce the number of grains per spike and the thousand-kernel weight. Similarly, Trnka et al. (2014) and FAO (2022) reported that in Central and Eastern Europe, wheat remains highly sensitive to water availability during April-June, particularly in regions dominated by rainfed production systems.

For maize (*Zea mays* L.), the Pearson correlation coefficient indicates a weak negative relationship between summer precipitation and production (r = -0.39), while the regression model explains only about 15% of the interannual variability ($R^2 \approx 0.15$). Although seemingly counterintuitive, this result aligns with recent evidence showing that in regions experiencing accelerated warming, thermal stress exerts a stronger influence on crop performance than total precipitation amounts (Lobell et al., 2011; Ray et al., 2015; IPCC, 2022). In years such as 2007, 2012, and 2020, extreme temperatures and high evapotranspiration coincided with critical phenological stages, reducing yields even when rainfall was not dramatically below average. The intraseasonal distribution of rainfall, the duration of heat waves, and soil water retention capacity are thus major limiting factors, weakening the direct relationship between summer precipitation totals and maize production.

For barley (*Hordeum vulgare* L.), the Pearson correlation coefficient indicates a very weak positive relationship between March-May precipitation and annual production (r = 0.10), while the regression model explains only about 1% of the interannual variability ($R^2 \approx 0.01$). This limited climatic sensitivity is consistent with the literature, which shows that barley has earlier phenology, a shorter vegetation cycle, and greater tolerance to early-spring hydric variability (Boian and Brezeanu, 2021; EEA, 2023). Moreover, barley yields are more strongly influenced by technological factors such as sowing density, fertilization levels, variety choice, and early spring temperatures, thereby reducing the apparent influence of precipitation on annual productivity.

The analysis of total cereal production indicates a moderate positive Pearson correlation with annual precipitation (r = 0.47), while the regression model explains approximately 22% of the interannual variability ($R^2 \approx 0.22$). These findings suggest that variability in the annual rainfall regime remains an important determinant of Romania's cereal sector performance. This result aligns with the conclusions of Simota and Dumitru (2014) and Spinoni et al. (2017), which demonstrated that the alternation of wet and dry years drives major fluctuations in agricultural output across Southeastern Europe.

Overall, the moderate or weak correlations obtained across cereals indicate that precipitation, although a key factor, does not act in isolation.

Extreme temperatures, atmospheric drought, soil water reserves, the timing and distribution of rainfall events, and technological management levels all significantly contribute to yield variability. This is further supported by international literature, which emphasizes the need to incorporate compound indicators - such as SPEI or potential evapotranspiration - in future agroclimatic analyses (Hersbach et al., 2020; IPCC, 2022).

CONCLUSIONS

The analysis of the relationship between precipitation patterns and cereal production in Romania over the period 1997-2024 reveals distinct yet crop-specific trends, with responses shaped by seasonal climatic variability.

The production of wheat (*Triticum aestivum* L.) shows a moderate positive correlation with precipitation levels recorded between April and June, confirming the importance of water availability during stem elongation and grain-filling stages. The coefficient of determination ($R^2 \approx 0.48$) indicates that nearly half of the interannual variability in wheat production can be statistically explained by spring precipitation, although additional climatic constraints and agronomic factors also contribute to yield fluctuations.

In the case of maize (*Zea mays* L.), the relationship between summer (June-August) precipitation and annual production is very weak and negative ($R^2 \approx 0.15$). This result indicates that high maize yields depend not only on summer rainfall, but also on water stored in the soil beforehand, the intra-monthly distribution of precipitation, and thermal stress during pollination. Maize remains the most vulnerable crop to combined atmospheric and soil drought.

For barley (*Hordeum vulgare* L.), the extremely low correlation with March-May precipitation ($R^2 \approx 0.01$) reflects the crop's greater resilience to rainfall variability and the stronger influence of other determinants such as genotype, technology, fertilization, and early-season temperature.

At national level, total cereal production shows a moderate positive correlation with annual precipitation ($R^2 \approx 0.22$). This finding demonstrates that, despite technological progress, year-to-year fluctuations in cereal yields remain strongly tied to hydrological variability - especially given the high share of precipitation-sensitive crops such as wheat and maize.

The strong dependence on rainfall confirms the predominantly non-irrigated character of Romanian agriculture and highlights several critical aspects:

• the essential role of precipitation in favourable agricultural years;

• the high exposure of the sector to climatic variability;

• the need to strengthen irrigation infrastructure, especially in southern and south-eastern regions.

Overall, the results show that wheat responds most predictably to seasonal precipitation levels, maize is the most vulnerable crop to combined drought and heat stress, barley is the least influenced by rainfall variability, and total cereal tends to increase with higher annual precipitation amounts.

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