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INFLUENCE OF CLIMATE, SOIL CONDITIONS, AND WATER USE EFFICIENCY ON MAIZE CULTIVATION: A COMPARATIVE BIBLIOGRAPHIC STUDY BETWEEN THE PERUVIAN COAST AND EASTERN ROMANIA

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Abstract. *Maize (Zea mays L.) is a staple crop whose productivity is strongly influenced by climatic factors, soil characteristics, and water availability. This study presents a comparative bibliographic analysis of maize cultivation under low-precipitation conditions on the Peruvian coast and in Eastern Romania. Both regions experience water scarcity, but their climatic and edaphic conditions differ significantly: the Peruvian coast exhibits an arid climate with minimal rainfall (generally below 100 mm per year) and high evapotranspiration, while Eastern Romania has a continental climate with seasonal droughts, irregular precipitation distribution (400-600 mm/year), and significant temperature variations during the growing season. This review analyzes the impact of precipitation, temperature, relative humidity, soil texture and water-holding capacity, water resource distribution, as well as germination time, duration of the phenological cycle, and potential maize yield in both contexts. Additionally, economic and cultural factors are considered, including water availability for irrigation, associated costs, and the influence of traditional agricultural practices on crop efficiency. The findings highlight the critical role of water management strategies, selection of drought-tolerant varieties, crop rotation, and soil conservation techniques as key elements to ensure maize resilience under changing climatic conditions. Recommendations for sustainable adaptation are provided, including optimized irrigation, improved soil fertility, efficient water distribution, and adoption of agroecological technologies, applicable to both regions, with the aim of sustaining productivity and reducing vulnerability to drought and climate change.*

Keywords*: Maize cultivation, climate variability, soil conditions, water use efficiency, drought adaptation, comparative study, sustainable agriculture, agroclimatic analysis*

INTRODUCTION

Maize (Zea mays L.) is one of the most indispensable and widely cultivated crops in the world, as it constitutes a fundamental source of food, animal feed, and biofuels (CIMMYT, 2025). In southeastern Romania and the Peruvian coast, maize is also of great relevance; however, its productivity is being strongly influenced by environmental factors such as temperature, precipitation, and soil fertility. Climate change has intensified drought periods, altered the distribution and patterns of rainfall, and increased evapotranspiration, making water availability a major limitation for maize growth and yield (JONES ET AL., 2017; LOBELL ET AL., 2014; IGLESIAS ET AL., 2023, SMULEAC ET AL., 2024).

Both regions exhibit marked contrasts in their climatic, edaphic, and topographic conditions. The southeastern region of Romania is characterized by a gradual transition from the Romanian Plain to the Dobruja Plateau and the Danube Delta, where the relief is predominantly flat or gently undulating. This region is crossed by the Danube River and extends to the Black Sea, featuring plains, low hills, and geologically ancient formations. These conditions determine soil distribution and water availability, which are further constrained by an irregular rainfall regime. The area presents a temperate continental climate, with warm and dry summers, cold winters, and an average annual precipitation ranging

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between 400 and 600 mm, concentrated mainly from May to July. However, rainfall is irregular, and recurrent summer droughts caused by heat waves have reduced maize yields by up to 30% in recent years (UKRAGROCONSULT, 2024; SUPERAGRONOM, 2024; AGERPRES, 2025). The increasing frequency of extreme heat events has also accelerated soil moisture loss and reduced pollination success, especially in rainfed areas (POPESCU ET AL., 2022). The predominant loamy soils (loamy chernozems and cambisols) are relatively fertile and retain moisture well; however, during prolonged droughts, productivity declines drastically (Tudor et al., 2022; Management Journal USAMV, 2024).

In contrast, the Peruvian coast is a narrow desert strip located between the Pacific Ocean and the Andes, characterized by an arid subtropical climate, annual precipitation below 50–100 mm, and high evapotranspiration rates (SENAMHI, 2020). It also exhibits a strong dependence on irrigation systems supplied by Andean rivers. Its relief includes fertile valleys, pampas, and cliffs shaped by tectonic activity, fluvial erosion, and wind action. Despite the extreme aridity, maize is extensively cultivated in irrigated valleys using water from Andean rivers and glacial melt, which compensates for the scarcity of rainfall (VÂTCĂ ET AL., 2021). Soils are predominantly sandy to sandy-loam, with low organic matter content and limited natural fertility, requiring high-efficiency irrigation systems and careful nutrient management to maintain productivity.

Despite their geographical and climatic differences, both regions share a common challenge: limited water availability for maize cultivation, which directly affects agricultural productivity. Although southwestern Romania has more fertile soils, recent droughts have severely reduced maize yields. In 2018, the average yield was 7.79 t/ha, whereas by 2024 it declined to approximately 3.8–4.08 t/ha; however, under adequate irrigation, farmers can achieve yields between 8 and 12 t/ha (MCMEEKIN, 2024; ARTA ALBA, 2019; LATIFUNDIST, 2024; ERNST, 2024). In contrast, the Peruvian coast maintains more stable production despite its harsh conditions, with an average yield of 4.87 t/ha; however, in regions such as Lima and Ica, yields reach 9.5–14 t/ha, and when hybrid varieties are used, production can increase to 14–17 t/ha (AGENCIA AGRARIA NOTICIAS, 2025).

In this context, the present study aims to conduct a comparative bibliographic analysis of the climatic, edaphic, and agronomic conditions of southeastern Romania and the Peruvian coast, with the objective of identifying similarities, differences, and potential improvement strategies to optimize maize production and water-use efficiency under increasing water stress.

MATERIAL AND METHODS

This research was conducted as a comparative literature review, synthesizing scientific literature, articles, reports, and statistical databases related to maize cultivation and climatic platforms (such as SENAMHI and MeteoRomania) on both the Peruvian coast and in southeastern Romania (Figure 1). Climatic variables (mean annual precipitation, temperature range, and relative humidity), edaphic variables (soil texture, water retention capacity, and fertility), and agronomic variables (germination period, phenological cycle, and yield potential) were evaluated.

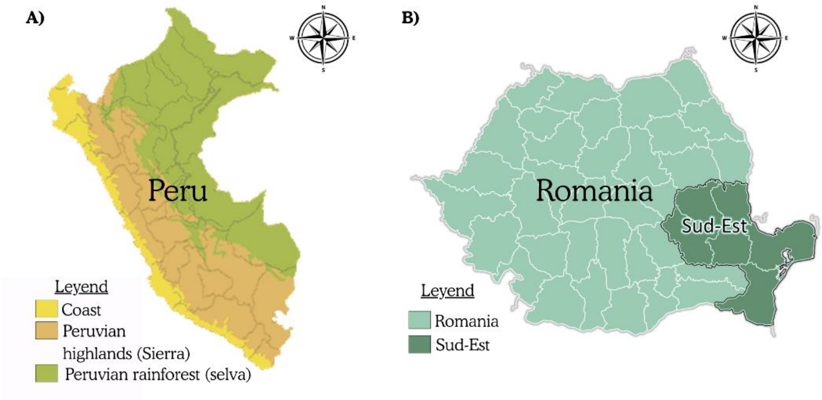

Figure 1. Geographical location of the Peruvian Coast and Sud-Est of Romania
Note. A) Peruvian Coast. B) Sud-Est of Romania. Created by the author, 2025.

RESULTS AND DISCUSSIONS

The climate comparison (Table 1) between the Peruvian coast shows extremely low rainfall (<100 mm/year), which generates a strong dependence on irrigation for maize cultivation (RODRÍGUEZ ET AL., 2019). In contrast, eastern Romania receives between 300 and 600 mm/year, but the distribution is irregular and high summer temperatures cause significant yield losses (UKRAGROCONSULT, 2024; AGERPRES, 2025). Regarding soil variables, the soils of the Peruvian coast are predominantly sandy in texture and have low water retention, with little organic matter content. In Romania, loam and clay loam soils predominate, with greater fertility and water retention capacity (TUDOR ET AL., 2022; Management Journal USAMV, 2024).

Table 1

Comparison of climatic variables in maize cultivation (Coast of Peru vs. Southeast of Romania)

Variables	Annual average precipitation	Annual average temperature	Average relative humidity	Extreme events
Coast of Peru	< 100 mm/year (arid desert climate)	18–25 °C (high daily thermal amplitude)	70% - 80% (constant marine influence)	Structural lack of rainfall and dependence on irrigation
Sud-Est of Romania	350-600 mm/year (semiarid continental climate)	11-20 °C (marked seasonal thermal amplitude)	55% - 65% (marked decrease in summer)	Severe summer droughts and heatwaves that reduce production by up to 30%

Note. Created by the author, with data collected from SENAMHI (2024), MeteoRomania (2025), Agerpres (2025), FAO (2023), UkrAgroConsult (2024) & Management Journal USAMV (2024).

This explains why, under the same water deficit conditions, Romanian plants maintain better root development and a more stable phenological cycle, although this is not sufficient for the entire development process. According to agronomic variables (Table 2), in Peru, maize germination occurs on average 5–7 days after sowing under irrigation, while in Romania the period can extend to 10–12 days due to temperature fluctuations.

Table 2

Comparison of agronomic variables of maize cultivation (Coastal Peru vs. Southeastern Romania)

Agronomic variable	Germination period	Total phenological cycle	Critical phase (flowering and grain filling)	Yield potential
Coast of Peru	5–7 days (under controlled irrigation and warm temperatures)	110–130 days (stable conditions)	Can remain stable with scheduled irrigation	9.5-14 t/ha under technified irrigation
Sud-Est of Romania	10–14 days (affected by water deficit and lower soil temperature)	140–160 days (extended due to thermal variability)	Shortened by heat stress >35 °C and low soil moisture	8–12 t/ha in normal years; up to 30% loss due to drought

Note. Created by the author, 2025.

The total phenological cycle (from emergence to physiological maturity) ranges from 110 to 130 days in Peru and 140–160 days in Romania (SENAMHI, 2024; RITCHIE & HANWAYS, 1982; BORCEAN, 2005). High temperatures in Eastern Europe shorten the flowering (VT–R1) and grain-filling (R3–R6) stages, as shown in Figure 2, reducing the final ear weight (FAO, 2023; VÂTCĂ ET AL., 2021). This increases the crop's exposure to environmental stress, as these stages are particularly sensitive to heat and drought. This is reflected in the percentage of yield loss; however, it also highlights the need to address adaptation and water management strategies, because even under favorable soil conditions, climatic stress limits productivity.

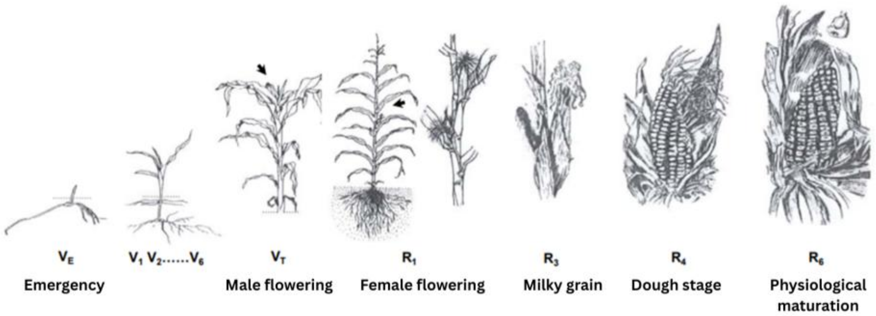

Figure 2. External changes in the maize plant scale of Ritchie and Hanways
Note. The scale of Ritchie and Hanway, 1982 was used. SENAMHI, 2025.

In Peru, water availability relies on highly efficient irrigation systems that utilize water from Andean rivers and glacial melt, allowing for relatively stable yields despite the aridity. In contrast, although the soils of southeastern Romania are more fertile, the limited irrigation infrastructure in some areas and the dependence on irregular rainfall increase the vulnerability of crops to heat waves and summer droughts.

These results also highlight the influence of socioeconomic factors and strategies on maize productivity and sustainable agriculture, as the availability of irrigation infrastructure, water use costs, and traditional farming practices limit producers' ability to implement efficient water management strategies (KRYSZAK ET AL., 2025). These limitations underscore the need for agricultural policies and support programs that facilitate access to sustainable technologies and promote the adoption of climate-adaptive practices.

Irrigation synchronization, adaptation of the agricultural calendar, and precise soil moisture monitoring are essential to minimize yield losses and optimize water use (BAHRASEMAN ET AL., 2025; LOPEZ ET AL., 2017). Among the most effective strategies are the selection of drought-tolerant maize varieties, crop rotation, moisture conservation through organic mulch, and irrigation optimization (WANG ET AL., 2025; XING ET AL., 2025; LIU ET AL., 2025).

In Romania, the implementation of techniques used in Peru, such as drip irrigation or controlled sprinkler irrigation, fertigation and the use of mulch, could reduce losses during critical phases such as flowering and grain filling, which have proven to be effective both locally and internationally, with success stories in Israel, northern Mexico and Spain (Almería), and likewise, with the use of controlled deficit irrigation (SERRANO ET AL., 2024, YASUOR ET AL., 2020; FISHMAN & LI, 2022, GARCÍA-SALDAÑA ET AL., 2019).

CONCLUSIONS

Comparative literature analysis confirms that, under water-scarce conditions, maize productivity is primarily determined by efficient water management and agronomic practices, rather than by isolated climatic or soil conditions. The Peruvian coast demonstrates that, even in an extremely arid environment with naturally low-fertility soils, stable yields can be maintained through advanced irrigation systems and intensive agronomic management. In contrast, southeastern Romania, despite having more fertile soils and greater water retention, exhibits greater productivity vulnerability to droughts and heat waves due to irregular rainfall and limitations in irrigation infrastructure.

Furthermore, it is concluded that the main limiting factor in Romania is not the longer duration of the maize phenological cycle, but rather prolonged exposure to high temperatures during critical phases such as flowering and grain filling. This condition increases heat and water stress, reduces the crop's physiological efficiency, and results in significant yield losses, even under favorable soil conditions.

Finally, the results highlight that adapting maize production systems to climate change requires a comprehensive approach that combines efficient water management, selection of drought- and heat-tolerant varieties, soil conservation practices, and strengthening of irrigation infrastructure. The transfer of successful experiences between regions, such as the irrigation and management strategies applied on the Peruvian coast and abroad, represents a concrete opportunity to improve crop resilience in vulnerable regions like southeastern Romania, with a focus on productive and agricultural sustainability.

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