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Drought-Induced Yield Decline in Maize (*Zea mays*) and Sunflower (*Helianthus annuus*) Crops a Case Study of Agricultural Vulnerability in Iași County, Romania

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ABSTRACT

In the past decade, concerns regarding climate change, and specifically the escalating threat of drought, have intensified across Europe, attributable to their substantial repercussions for agricultural systems and ecological integrity. The rising trend of global temperatures and significant alterations in precipitation patterns present formidable challenges for Romania, which is currently experiencing extended periods of drought. The prevailing conditions have profoundly impacted agricultural production, leading to significant economic and social consequences. In Iași County, the impact of drought has profoundly compromised the growth of maize (*Zea mays*) and sunflower crops, both of which rely heavily on adequate soil moisture for their optimal development. In contrast to the droughts experienced in 2020 and 2022, during which farmers noted reductions in production for the aforementioned crops, the primary data for 2024 indicate an average yield loss extent of 74% for maize (*Zea mays*) and 64% for sunflowers (*Helianthus annuus*) within the rural settlements of Iași County. The findings as well as the results indicate that agricultural producers experienced considerable economic setbacks, which were partially mitigated by government assistance programs designed to compensate agricultural growers for drought-impacted crops. Additionally, there is a pressing necessity for investment in the advancement and modernization of irrigation infrastructure.

Keywords: aridic conditions/drought, agro-climatological resilience, *Zea mays*, *Helianthus annuus*, agronomic productivity deficits, regional vulnerability assessment (Iași), hydric resource management.

INTRODUCTION

Agricultural Drought as an Escalating Global Challenge

Drought represents a significant and enduring natural hazard to agriculture, exerting profound influences on the farming industry, the rural economy, and overall food security. Across the globe, there has been a notable rise in both the frequency and severity of droughts in recent decades, a trend that is intricately linked to and exacerbated by climate change (Dobri et al., 2021; Rakovec et al., 2022).

The agricultural sector is invariably the first to be impacted when drought conditions emerge. According to FAO statistics (2023), it is projected that for the 2006-2022 period, the agricultural sector accounted for as much as 80% of the total damage and losses attributable to drought (FAO, 2023). Considering that around 1.3 billion individuals, constituting roughly 40% of the global populace, rely on agriculture for their sustenance, the ramifications of drought are acutely experienced in the welfare of numerous rural communities. The phenomenon of drought significantly diminishes the accessibility of water resources essential for irrigation and livestock, adversely impacting plant development and, in turn, food production, which ultimately jeopardizes food security. The economic implications are considerable: it is estimated that over the past thirty years, a staggering USD 3.8 trillion in agricultural output (encompassing both crops and livestock) has been forfeited due to natural calamities, such as droughts. This

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equates to an average loss of USD 123 billion annually, representing approximately 5% of the global agricultural GDP each year (Pek and Salman, 2023). Regarding risk and uncertainty, it follows that drought-related phenomena rank among the most prevalent natural hazards, characterized by their frequency, the extent of affected regions, and the populations impacted (Blauhut, 2022; Biella et al., 2024). FAO data indicates that the proportion of land area experiencing severe and extreme drought has increased twofold over the past four decades. Furthermore, agricultural losses from 2007 to 2022 represented, on average, 23% of the overall impact of disasters across all sectors, with drought accounting for more than 65% of total losses (IPCC, 2022; UNDRR, 2022).

European Context: Recent Aridic Episodes and Their Repercussions

In Europe, extensive regions faced severe drought conditions in the years 2015, 2018, 2022, 2023, and 2024, underscoring the susceptibility of agriculture to the far-reaching impacts of water scarcity (Brás et al., 2021; Biella et al., 2024; Ioniță et al., 2024). Within the various subsectors, crops and livestock account for the most significant losses. Climate change intensifies these impacts by elevating temperatures and altering precipitation patterns, resulting in more frequent, severe, and prolonged droughts (IPCC, 2022). The ramifications of drought extend well beyond the confines of agriculture, engendering significant socio-economic consequences - such as famine, migration, degradation of natural resources, and heightened socio-economic tensions - in regions that are severely impacted (UNCCD, 2022). Furthermore, these conditions can exacerbate instability in nations reliant on subsistence farming practices.

The most acute drought episodes of 2022 and 2024 exerted considerable repercussions on European agriculture; however, they manifested with distinct characteristics and stemmed from diverse etiological factors leading to varied outcomes (Ioniţă et al., 2025). Specifically, the 2022 European drought was largely attributable to anomalous meteorological conditions, encompassing unprecedentedly high temperatures and critically deficient precipitation. This particular event inflicted devastating consequences upon the agricultural sector, with particular detriment to cereal grain and oilseed crop yields. The 2022 aridic episode is documented as the most acute hydric deficit experienced across the European landmass in five centuries (Toreti et al., 2022); concurrently, the annum 2024 has been formally designated the period of maximal thermal intensity within the annals of systematic meteorological observation, according to the *European Climate Report* (Copernicus Climate Change Service, 2025). The 2024 drought, exacerbated by the impacts of climate change, led to prolonged and more severe conditions affecting both agricultural practices and water resources. This situation was further intensified by recurrent droughts across numerous European regions, resulting in a significant accumulation of soil water stress. In 2024, the repercussions were evident not only in diminished crop yields but also in escalated production costs and increased food prices within domestic markets.

Consequently, whereas the perceived magnitude of the 2022 drought led to its classification as an anomalous occurrence, 2024 evinced a discernible trajectory towards droughts of augmented intensity. This development not only underscores climate change's transmutation from a nebulous portent into a palpable verity but also establishes the critical exigency for formulating protracted strategies to safeguard the enduring viability of European agriculture.

Drought Vulnerability and Agricultural Impact in Romania

The repercussions of anthropogenic climate change on Romania's agricultural productivity have been subjected to exhaustive investigation, employing a diverse array of methodological paradigms - including sophisticated climate modeling, advanced crop simulation systems, and rigorous data analytics. These approaches facilitate a nuanced inquiry into climatological influences on crop viability, soil integrity, and the prospective challenges confronting Romanian agricultural practitioners within an increasingly precarious agrarian ecosystem (Caian and Lazăr, 2025; World Bank, 2025).

Furthermore, the corpus of documented research consistently elucidates the profound systemic alterations impacting Romanian agriculture, largely precipitated by the escalating incidence and severity of aridic episodes. Such effects are particularly conspicuous in the nation's southern and eastern territories - pivotal agricultural zones encompassing the Romanian Plain, Dobrudja, and southern and central Moldova (Ioniţă et al., 2025). The aforementioned territories are manifesting a discernible trend towards heightened aridification (Cheval et al., 2022), a development primarily attributable to erratic pluviometric distribution. This pattern is characterized by high-intensity precipitation events interspersed with protracted aridic episodes (Dobri et al., 2021). Such climatological volatility significantly impinges upon the agrarian sector, thereby curtailing the productivity of maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivars, which are integral to the nation's agricultural economy (Ontel et al., 2021). Prevailing scholarly concerns, particularly pertinent to the scope of the present investigation, encompass several critical dimensions: drought-induced alterations in agronomic productivity (Prăvălie et al., 2017; Blauhut, 2022) and associated qualitative degradation of produce (Petcu et al., 2001; Cojocaru et al., 2023), with specific emphasis on the ramifications of hydric deficits for sustainable water resource management and overarching ecosystemic integrity (Corduneanu et al., 2021).

Research Rationale, Objectives, and Scope of the Present Study

The present study endeavors to conduct a rigorous analysis of the repercussions of drought phenomena on maize (*Zea mays*) and sunflower cultivation within Iași County. Furthermore, an examination of the prevailing national and international paradigms concerning the phenomenological progression and analytical assessment of such climatological hazards will serve to elucidate: (i) their far-reaching implications for the agro-alimentary systems at local, regional, and national scales; (ii) the profound socio-economic consequences emanating from drought-induced detriments; and (iii) requisite adaptive strategies for the agricultural sector when confronted with this genre of environmental incertitude.

MATERIAL AND METHODS

Contextual Framework: Drought as a Recurrent Hazard in Romanian Agriculture

Aridic phenomena constitute one of the paramount challenges confronting global agriculture, and Romania, with its substantial agrarian economy, is profoundly susceptible to this climatological adversity (Nagavciuc et al., 2022). Over recent decades, the recurrence and magnitude of such desiccation events have demonstrably escalated, a trend largely propelled by anthropogenic climate change. The aridic episodes recorded in 2022 and 2024, for instance, number among the most acute within the nation's contemporary annals, imposing extensive deleterious impacts on both agricultural output and hydric resources (Caian and Lazăr, 2025).

Historically, Romania has periodically contended with substantial arid episodes, which have detrimentally affected nationwide agricultural productivity (Fischer et al., 2024). The 1946 desiccation event, for instance, precipitated a profound crisis encompassing both agrarian and humanitarian dimensions, with the ensuing 1947 famine manifesting with exceptional severity, particularly in Moldova. More contemporaneously, notable occurrences include the droughts of 2007 and 2012, and preeminently the acute arid event of 2020, which was subsequently succeeded by a further significant episode in 2022. Assessments undertaken by the World Bank demonstrate a discernible escalation in both the recurrence and magnitude of droughts within Romania over the preceding half-century. This observed trajectory is, in part, attributed to anthropogenic climate change, a phenomenon recognized for exacerbating extreme meteorological events (World Bank, 2023). The repercussions of such aridic phenomena on approximately 2.5 million hectares cultivated with maize (*Zea mays*) precipitated yield deficits of 30-50% within Romania's southern and eastern territories in 2022 (MADR, 2023); furthermore, climatological projections indicate a prospective diminution in yields of 10-25% by 2050, should requisite adaptive strategies not be implemented (IPCC, 2022). Romania is distinguished as Europe's principal cultivator of sunflowers (*Helianthus annuus*), a crop characterized by its notable thermotolerance and modest hydric requirements. Notwithstanding this inherent resilience, the 2020 drought engendered a 20% reduction in harvest volumes relative to the preceding quinquennial average (Eurostat, 2021). Concurrently, escalating ambient temperatures detrimentally influenced the oleaginous content of the seeds, thereby impairing their qualitative attributes (Cojocaru et al., 2023).

Within this framework, scholarly inquiry that combines agronomic management strategies with technological advancements is increasingly recognized as an indispensable instrument for informing the formulation of robust agricultural policies. Illustratively, Caian et al. (2024) undertook a comprehensive examination of critical agro-climatological parameters in Romania, with particular attention to thermal regimes, precipitation patterns, and pedo-hydrological dynamics, leveraging high-resolution CORDEX models. Their investigation accentuated the pronounced vulnerability of Romania's southern territories to acute thermal stress episodes and recurrent aridic phenomena, concurrently furnishing detailed spatiotemporal projections for maize (*Zea mays*) and wheat yields under a spectrum of diverse future scenarios. The aforementioned 2025 study by Caian and Lazăr constituted the inaugural prospective analysis for maize (*Zea mays*) within southeastern Europe, inclusive of Romania, and concomitantly scrutinized the influence of seeding temporalities, nutrient management strategies, and diverse climatological stressors on ultimate yield parameters. Subsequent research by Caian and Amihăesei (2023) further explores the domain of maize (*Zea mays*) cultivation, introducing a sophisticated modeling framework designed for the identification of optimal maize (*Zea mays*) ideotypes through the systematic application of genetic algorithms. This advanced methodological approach endeavors to ascertain superior maize (*Zea mays*) genotypes and corresponding agronomic protocols that demonstrate robust suitability for a dynamically evolving climatic milieu.

Data Acquisition and Sources

The present investigation endeavors to scrutinize the repercussions of the 2024 aridic episode on maize (*Zea mays*) and sunflower (*Helianthus annuus*) agro-industrial output within Iași County, leveraging a methodological framework predicated upon the systematic collation and critical interpretation of pertinent climatological and agronomic datasets. Empirical data underpinning this study are procured from authoritative institutional repositories, notably the *National Meteorological Agency* (ANM), the *Ministry of Agriculture and Rural Development* (MADR), and the *Iași County Directorate for Agriculture* (DAJ Iași).

Analytical Parameters and Indicators Employed

Key analytical parameters incorporated herein encompass: (i) agrarian acreage deleteriously affected by hydric stress, disaggregated to the communal administrative echelon; (ii) quantifiable deficits in crop yields for the aforementioned cultivars, expressed as metric tons per hectare; and (iii) intra-annual distribution patterns of pluviometric and thermal data at the county level, all subjected to meticulous examination via official meteorological records. Furthermore, the spatial allocation of irrigation infrastructure throughout the county underwent rigorous assessment, delineating zones with operational irrigation systems and juxtaposing these with locales where deficient irrigation demonstrably amplified the adverse consequences of drought.

Data Processing and Analytical Methodologies

Quantitative Statistical Analysis

The collated datasets were subjected to systematic processing, employing a diverse array of quantitative, statistical, and geospatial analytical techniques.

Geospatial Analysis and Cartographic Representation (QGIS)

These methodologies encompassed cartographic representation via QGIS 16.5 and the application of various data visualization instruments - such as radar charts, sunburst diagrams, histograms, and stacked area charts - to elucidate the interdependencies among diminished pluviometric levels, anomalous thermal oscillations, and consequent deficits in agricultural output.

Comparative Assessment and Vulnerability Stratification Framework

The overarching objective was to undertake a rigorous comparative assessment between territories exhibiting maximal adverse impacts and those demonstrating minimal effects. This involved discerning the pivotal determinants conditioning agronomic resilience, appraising the efficacy of implemented hydric management interventions, and formulating policy-relevant recommendations designed to attenuate the agricultural sector's vulnerability to extreme climatological phenomena.

RESULTS AND DISCUSSION

General Climatic Context and Agricultural Vulnerability in Iași County

Romania is characterized by a pronounced continental climatic regime, featuring torrid, xeric summers and severe hibernal periods, thereby rendering particular regions acutely susceptible to substantial aridic episodes. Locales manifesting maximal vulnerability to such hydric stress are predominantly situated in the southern and eastern sectors of the country, distinguished by diminished mean annual precipitation levels (with certain zones registering sub-500 mm annually) and augmented rates of evapotranspirative water loss during the estival months. Iași County, positioned within the northeastern Moldova region, is subject to a continental climate punctuated by xeric influences throughout particular summers. Its mean annual pluviometric input typically ranges from 550 to 600 mm, a volume frequently suboptimal for satisfying the optimal hydric requirements of principal agronomic cultivars. Consequently, these prevailing climatic characteristics indicate that during years of pronounced aridity, Iași County and the broader Moldovan region experience significant pedo-hydrological deficits (manifesting as pedological drought), which critically impair agricultural productivity.

Romania encompasses approximately 14 million hectares allocated for agrarian activities, of which nearly 9.3 million are designated as cultivable terrain. Notwithstanding the dedication of over half (57%) of the national territory to such pursuits and the engagement of circa 18% of the nation's labor force within this domain, agriculture's aggregate contribution to the Gross Domestic Product (GDP) remains comparatively circumscribed, representing approximately 4% of the total GDP (World Bank, 2024). The substantial agrarian populace and extensive agricultural territories, in conjunction with persistently suboptimal productivity levels, accentuate an inherent socio-economic vulnerability, particularly when confronted by environmental perturbations such as aridic episodes. A salient compounding factor is that a significant proportion of Romanian agricultural producers comprises small-scale operations engaged in subsistence or semi-subsistence farming - predominantly family-operated holdings - which command minimal resources for effectuating adaptive measures (e.g., irrigation infrastructure and contingency support systems) and are immediately dependent upon the stochastic nature of meteorological conditions.

Recent Pluviometric and Thermal Trends in Iași County (2020-2024)

Under a climatic regime analogous to that prevailing across the broader Moldovan territory, Iași County confronted a substantial hydric deficit in 2024. Pluviometric inputs during this period registered 30-50% below the long-term mean, an insufficiency particularly pronounced during critical phenological stages for key cultivars: May-June for sunflowers and July-August for maize (*Zea mays*). Consequently, communes situated within the county's austral sector - notably Șipote, Dănești, and Miroslava - were subjected to the most acute repercussions, with annual precipitation totals frequently falling below 250 mm. Conversely, the minimal pluviometric threshold deemed requisite for successful maize (*Zea mays*) agronomy typically ranges between 400 and 500 mm per annum. The boreal sectors of the county, including specifically the Dorohoi and Hârlău vicinities, experienced a comparatively attenuated impact, attributable to the incidence of spatially circumscribed precipitation events within discrete micro-localities.

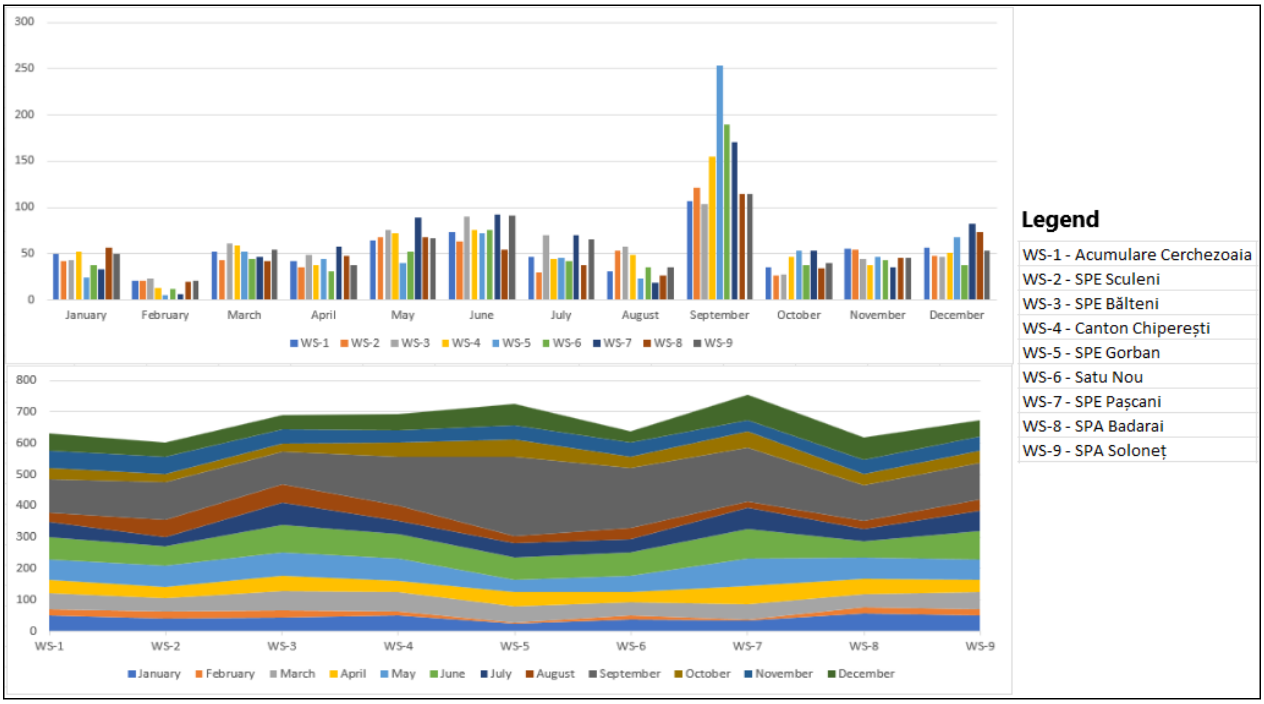
Current empirical data indicate that 2022 constituted the most arid year in recent documented history, with pluviometric inputs diminishing by approximately 40% relative to the multiannual normative mean. While 2023 evidenced a marginal amelioration in hydric conditions, the spatiotemporal distribution of precipitation remained notably erratic, thereby sustaining the prevailing aridification trajectory into 2024. Correspondingly, groundwater table elevations have registered a diminution of 1.5 to 2 meters compared to 2023 levels (Păltineanu et al., 2024), and the Bahlui riverine system has recorded its minimal discharge rate observed over the preceding three decades.

Table 1. A Quinquennial Analysis of Key Meteorological Parameters for Iași County, Focusing on Precipitation and Temperature Regimes (2020-2024)

Observation year	Total Annual Pluviometric Volume (mm/year)	Deviation from Multiannual Mean Precipitation (%)	Absolute Annual Maximum Temperature (°C)
2020	450 mm	-25%	38.5°C (record)
2021	520 mm	-15%	36.2°C
2022	380 mm	-40% (extreme drought)	39.1°C (new record)
2023	600 mm	+5%	34.8°C
2024*	310 mm (*until July)	-35%	37.6°C

Source: ANM Iași, 2024 [The Moldova Regional Meteorological Centre (CMR Moldova) of the National Meteorological Administration (ANM), headquartered in Iași, 2024].

Data from Table 1 for Iași County over the quinquennial period 2020–2024, discloses a disquieting trajectory indicative of an escalating frequency of anomalous meteorological occurrences. This emergent pattern possesses direct ramifications for the agrarian sector, particularly concerning cultivars that demonstrate pronounced susceptibility to hydric deficits, exemplified by maize (*Zea mays*) and sunflowers. The year 2022 is particularly distinguished by its exceptionally deficient pluviometric input, amounting to a mere 380 mm. This figure represents a substantial negative anomaly of 40% relative to the multiannual normative value, leading to its formal classification as a period of "extreme drought". The substantial pluviometric deficit was concomitant with an unprecedented thermal apogee of 39.1°C; this confluence of factors exacerbated evapotranspirative processes and perceptibly depleted pedohydric reserves throughout the critical vegetative cycle. As a direct corollary, maize (*Zea mays*) yields contracted to 4.5 t/ha, signifying a 40% diminution relative to normative levels, whereas sunflower yields experienced a precipitous decline to a nominal 1.8 t/ha. This quantitative reduction was paralleled by a significant deterioration in qualitative attributes, with oleaginous concentrations diminishing to 38%, a figure representing a deviation of seven percentage points below the established standard. Empirical evidence substantiates an explicit correlation between such anomalous meteorological occurrences and deficits in agronomic output, thereby accentuating the exigency for prompt, strategic interventions to recalibrate regional agricultural practices in alignment with the manifest realities of climate change. Such interventions necessitate the deployment of aridity-tolerant cultivars, the augmentation and optimization of hydric management infrastructure, and the adoption of proactive, predictive agrometeorological frameworks on a regionalized basis.



Source: Own computations.

Figure 1. Temporal Distribution of Monthly Pluviometric Totals in Iași County (2024)

The preceding graphical representation delineates the pluviometric distribution patterns recorded throughout 2024 from a network of nine meteorological observatories (WS-1 to WS-9). These data accentuate a period of protracted aridic conditions that critically affect agronomic cultivars, with notable repercussions for maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivation. Empirical evidence indicates a substantial diminution in pluviometric input throughout the preponderance of the annual cycle, save for a notable anomaly in September when atypically high precipitation levels were registered. However, this uneven temporal distribution of rainfall, predominantly confined to a single monthly interval, fails to sufficiently ameliorate the hydric deficit accrued during pivotal phenological stages essential for optimal crop development.

Intra-Annual Precipitation Dynamics and Their Agronomic Significance

The agronomic production of maize (*Zea mays*) and sunflower cultivars is inherently circumscribed by discrete vegetative cycles, each necessitating an adequate provision of hydric resources. Specifically, the cultivation lifecycle for maize (*Zea mays*) is typically initiated in April and persists throughout its period of maximal hydric demand, predominantly spanning the May to August timeframe. The preceding graphical representation (Figure 1) elucidates a discernible deficiency in pluviometric input during these pivotal developmental phases, which are indispensable for the optimal maturation of the aforementioned cultivars.

Within scholarly discourse, droughts of moderate severity are operationally defined as temporal episodes wherein pluviometric inputs attain only 70-80% of the established climatological norm, concomitant with positive thermal anomalies registering between 1.0 and 1.5°C above the long-term mean. Current empirical observations for 2024 reveal meteorological parameters indicative of even more substantial deficits persisting throughout the entirety of the vegetative cycle. This suggests the manifestation of an aridic episode of considerable magnitude, one that unequivocally transcends the established criteria defining moderate drought conditions.

Spatial Heterogeneity of Drought Impact and Contributing Factors

The aforementioned graphical depiction illustrates the 2024 pluviometric dispersion across a matrix of nine meteorological stations (WS-1 to WS-9), thereby highlighting persistent arid conditions with substantial deleterious consequences for key agricultural cultivars such as maize (*Zea mays*) and sunflowers (*Helianthus annuus*). Analysis of the dataset reveals a marked reduction in precipitation for the predominant part of the year, with a singular deviation in September, a month characterized by augmented rainfall. Such an erratic pattern of pluviometric allocation, largely confined to one isolated month, proves insufficient to rectify the cumulative hydric deficiency established during the critical vegetative phases vital for crop maturation.

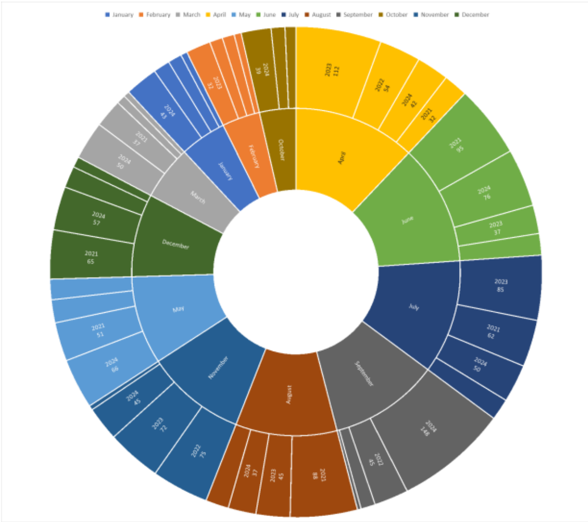
A meticulous scrutiny of data collated from the nine designated meteorological observatories reveals conspicuous heterogeneities in the spatial distribution of pluviometric inputs.

- Meteorological observatories WS-3 and WS-7 register the maximal aggregate annual pluviometric inputs, frequently exceeding 700 mm, with significant contributions recorded predominantly in September and December.

- Observatory WS-5 is distinguished by its diminished pluviometric inputs during the first semester (January-June), thereby compounding the hydric shortfall throughout the critical phenological window for vernal agricultural cultivars.

- Observatories WS-1, WS-2, WS-6, and WS-8 document medial pluviometric totals, demonstrating an analogous temporal dispersion characterized by scant precipitation throughout the vernal and estival periods.

The discerned geospatial heterogeneity may be attributed to orographic influences, contiguity with significant sources of atmospheric moisture, or the prevailing dynamics of regional atmospheric circulation. A rigorous assessment of the repercussions of aridic conditions mandates the systematic correlation of these empirical datasets with the specific edaphic properties and differential hydric requirements of the cultivars under production proximate to each meteorological observatory.



Source: Own computations.
N.B. Annums of Pronounced Estival Aridity Impacting Key Agronomical Timelines (May-August)

Figure 2. Intra-annual Pluviometric Distribution for Iași County (Quinquennial Period: 2020-2024)

Differential Crop Vulnerability and Compounded Impacts

The period extending from late vernal through the estival months, specifically May to August, constitutes a pivotal temporal window for Romanian agronomy. This timeframe coincides with essential phenological stages of principal field cultivars, including foliar development, inflorescence emergence (heading), anthesis (flowering), initial seed development (grain formation), and subsequent grain maturation (filling). Optimally, this interval necessitates an equitable and consistent distribution of pluviometric inputs, with a minimal monthly precipitation approximating 60-70 mm, to adequately satisfy the intricate phytophysiological requirements of these plants.

The annum 2021 manifested as an agricultural period distinguished by pronounced anomalies in pluviometric regimes, which culminated in an erratic spatiotemporal dispersion of precipitation throughout the critical vegetative cycle. In April, recorded pluviometric inputs amounted to a nominal 32 mm, a figure markedly inferior to the multiannual normative value; this deficit consequently exerted a detrimental influence upon seed germination and the early ontogenetic stages of vernal cultivars. May, registering 51 mm, perpetuated this hydric insufficiency, whereas June afforded only a marginal amelioration with 95 mm of precipitation. Such acute temporal variability in rainfall is intrinsically linked to inconsistent pedohydric conditions, thereby predisposing cultivars like maize (*Zea mays*) and sunflower (*Helianthus annuus*) to the potential onset of intermittent hydric stress. Subsequently, August was characterized by a significant pluviometric deficit of 38 mm, indicative of a phase of edaphic aridity during the terminal stages of plant development.

Data from all meteorological observatories for September register a conspicuous aggregation of pluviometric inputs, visually corroborated by a prominent dark grey sector in the accompanying graphical representation. Such a distributional characteristic is indicative of a significant atmospheric event, putatively associated with the advection of frontal systems or regional cyclonic activity, which has influenced the entirety of the monitored domain. Notwithstanding this, the substantial precipitation recorded in September materialized at a delayed juncture within the ontogenetic progression of the cultivars under examination. This occurred at a temporal point wherein the preponderance of the plant stand had already surpassed the critical phenological phases integral to vegetative development and ultimate yield determination.

Throughout the 2022 observation period, while aggregate pluviometric data might ostensibly suggest an equitable overall distribution, the spatiotemporal dispersion of these inputs reveals substantial irregularities, posing considerable analytical complexities. For instance, April recorded a mean precipitation of 54 mm, whereas August registered 88 mm, figures indicative of potential high-intensity pluvial episodes. Such augmented precipitation volumes, when lacking uniform temporal dispersion, are plausibly associated with an accentuated surface hydrological runoff. This phenomenon typically manifests as diminished pedo-hydric infiltration, consequently amplifying the predisposition to edaphic aridity within agriculturally productive soil strata. Although a lacuna in the May dataset introduces an analytical impediment, extant data intimate a comparatively moderate hydric regime during the capitulum development phase for sunflowers and the ear (spadix) development phase for maize (*Zea mays*).

The annum 2023 manifested as a period distinguished by idiosyncratic/particular pluviometric regimes, thereby unveiling profound ramifications for the prevailing comprehension of climatological dynamics. A conspicuous deviation in precipitation patterns was documented: April registered a substantial pluviometric accumulation of 112 mm, which stands in stark juxtaposition to an atypically xeric June that recorded a nominal 37 mm. Such acute perturbations within the hydric cycle exert considerable influence upon the ontogenetic trajectory of cultivated species, particularly those with augmented resource requirements during the June-July temporal window. Although July evidenced a modest amelioration, with pluviometric inputs attaining 85 mm, the phytophysiological trauma engendered by antecedent hydric stress may well persist without substantive mitigation. This conjuncture serves to underscore the incrementally precarious attributes of the regional climatic paradigm.

The annum 2024 initially manifests what might be perceived as a comparatively balanced pluviometric regime; however, a closer examination reveals a systemic hydric deficit during the estival period. Empirical data for 2024 intimate a marginal reversion to normative precipitation levels, with pluviometric inputs recorded at 54 mm in April, 66 mm in May, and 76 mm in June. Notwithstanding these figures, August persists as a month engendering significant concern, registering a nominal pluviometric input of merely 37 mm. This pattern suggests a recurrent deficiency in summer water availability, a circumstance that accentuates abiotic stress and precipitates consequential deficits in agronomic production. The comparatively subdued precipitation levels observed throughout this critical timeframe are insufficient to ensure consistent pedohydric saturation, thereby compromising effective soil moisture retention and, by extension, diminishing overall agricultural yields.

Acute hydrological disequilibrium - a recurrent feature of the autumnal and hibernal seasons

The autumnal (September-November) and hibernal (December-February) periods are of paramount importance for the replenishment of pedohydric reserves and the optimal conditioning of agrarian terrains for the ensuing agricultural cycle. October characteristically records scant pluviometric input, as exemplified by figures of 39 mm in 2021 and 32 mm in 2023. Such deficient precipitation levels critically imperil autumn-sown cultivars (e.g., wheat, barley, rapeseed), detrimentally affecting both the uniformity of seedling establishment and their subsequent hibernal hardiness. In the absence of adequate soil hydration, these cultivars exhibit compromised root anchorage, rendering them acutely susceptible to cryogenic stress (frost) and the adverse effects of strong aeolian forces.

In specific annual cycles, December may register substantial pluviometric inputs (e.g., 65 mm in 2021), potentially indicative of a belated amelioration of antecedent hydric deficits. Notwithstanding this, such precipitation frequently manifests as solid-phase water (i.e., snow), thereby failing to meaningfully augment the soil moisture reserves readily accessible to agricultural cultivars. Conversely, February persistently demonstrates a marked pluviometric deficiency (e.g., 32 mm in 2023). This circumstance amplifies the probability of initiating the vernal season with edaphic conditions characterized by pronounced aridity. Such a scenario is particularly pertinent within Romania's orographic and planitian/lowland zones, where evapotranspirative demand typically undergoes rapid intensification with the advent of March.

March and September - notable meteorological volatility and significant influence on agricultural systems

Under particular circumstances, exemplified by March 2024 which registered a nominal pluviometric input of merely 31 mm, prevailing hydric conditions are frequently insufficient to support robust vegetative regeneration. Such deficiencies detrimentally affect perennial agroecosystems, encompassing pomicultural/ orchard and viticultural (vine) plantations, in addition to autumn-sown cereal cultivars. This observation is of considerable import within an agronomic context, given that cultivated species rapidly reactivate their physiological metabolic functions during the vernal resurgence of biological activity, a period necessitating readily accessible pedohydric reserves.

The month of September is characterized by a pronounced convergence of pluviometric activity across all monitored meteorological stations, a feature visually underscored by a prominent dark grey demarcation in the pertinent graphical data. Such a distinctive pattern strongly suggests a large-scale atmospheric disturbance, plausibly attributable to the influence of synoptic-scale frontal dynamics or cyclonic circulations affecting the entirety of the study region. However, this significant ingress of moisture during September occurred at a temporally delayed stage in the agricultural timeline, largely subsequent to the culmination of critical ontogenetic phases dictating vegetative vigor and ultimate crop yield.

Overall Climatic Trends and Systemic Agricultural Challenges

The heterogeneous dispersion of intra-annual pluviometric inputs is exhibiting heightened discernibility throughout the period under scrutiny, a phenomenon underscoring the tangible ramifications of regional climatic shifts. These ramifications notably encompass protracted aridic episodes and an augmentation in storm severity, including occurrences such as significant hailfall and high-velocity aeolian disturbances. Such pronounced meteorological instability constitutes formidable impediments to both coherent agronomic strategic planning and the judicious stewardship of hydric resources.

The biennium spanning 2020-2021 was distinguished by pronounced xeric conditions within Iași County, whereas the subsequent 2023-2024 period has been characterized by a marked oscillation between episodes of excessive pluviation and severe aridic events. Such a fluctuating climatic regime impugns the efficacy of conventional agronomic forecasting methodologies and mandates the deployment of sophisticated, dynamic agro-climatological models. It is imperative that pertinent climatological data be systematically integrated into prodromal alert systems and tailored, localized agrarian adaptation strategies. Moreover, the enhancement of targeted irrigation techniques and pluvial water harvesting capabilities is of critical importance in regions subject to erratic precipitation patterns.

Protracted aridic episodes have invariably precipitated acute financial detriments for agricultural producers. The impairment of cultivars typically culminates in irrecoverable expenditures, encompassing antecedent production outlays (e.g., for seeding materials, labor, and pedological ameliorants) which were previously committed, often through credit mechanisms that subsequently accrue as debt. For instance, during 2020, a notable segment of agriculturalists was unable to satisfy their contractual obligations to grain merchants, consequently incurring pecuniary penalties or substantial liabilities to purveyors of essential agricultural inputs. A considerable number of farming enterprises were compelled to relinquish their anticipated harvests. This situation triggered a cascade of deleterious financial repercussions: producers with severely compromised yields found themselves incapacitated from servicing extant loans or discharging debts related to credit-financed procurement of agricultural requisites (such as seeds and agrochemicals), thereby extending adverse impacts to supply conglomerates and financial institutions. Governmental authorities instituted programs for financial compensation and debt deferral, albeit with selective application and at a level frequently perceived as inadequate by the agrarian community. While 2023 witnessed a marginal augmentation in overall production, a concomitant deterioration in crop quality was observed, attributable to the emergence of a mycological pathogen affecting maize (*Zea mays*), a development linked to erratic hygrometric conditions (Petcu et al., 2023).

Crop-Specific Impacts and Projections

The annum 2022 represented an exceptionally exigent period for sunflower (*Helianthus annuus*) cultivation; oleaginous concentrations within the seeds diminished to levels inferior to 40%, a circumstance that precipitated tangible repercussions for market valuations. While agronomic output in 2023 was deemed adequate, it was nonetheless characterized by diminished seed dimensions. Conversely, the prospective 2024 harvest is anticipated to be suboptimal, primarily attributable to insufficient hydric resources during the critical anthesis (flowering) phase. The pronounced oscillations observed in maize (*Zea mays*) and sunflower (*Helianthus annuus*) productivity within Iași County throughout the 2020-2024 quinquennium are largely ascribed to an incrementally degrading regional climatic regime. Table 2 furnishes a compendium of the principal circumstances and environmental determinants that have demonstrably influenced the trajectory of agricultural development in the aforementioned locale.

Table 2 also furnishes a detailed exposition of the temporal evolution of maize (*Zea mays*) and sunflower (*Helianthus annuus*) agronomic output within Iași County for the quinquennial period 2020-2024. This presentation particularly accentuates the repercussions of inherent climatological variability - notably edaphic and atmospheric aridity-upon the productivity of these specific cultivars. The accompanying analytical framework provides a rigorous scientific interpretation of the empirical data, establishing a discernible nexus between observed trends in agronomic productivity and prevailing limiting climatological factors.

This discernible diminution is indicative of a calculated adaptive response on the part of agricultural producers, largely precipitated by the inherent instability of evolving climatic conditions and the persistent economic detriments experienced during agricultural cycles compromised by severe hydric stress.

Table 2. Analysis of Yield Diminution for *Zea mays* (Maize) and *Helianthus annuus* (Sunflower) in Iași County (2020-2024)

Reporting Year	Area under Cultivation (hectares)		Agronomic Yield (t/ha)		Percentage Deviation from Multiannual Mean (%)	
	Maize (*Zea mays*)	Sunflower (*Helianthus annuus)*	Maize (*Zea mays)*	Sunflower (*Helianthus annuus*)	Maize *(Zea mays)* (Yield Deviation)	Sunflower (*Helianthus annuus*) (Oleaginous Content Deviation)
2020	95,000	45,000	6.2	2.3	-18%	42% (-3%)
2021	93,500	46,200	7.1	2.6	-6%	44% (-1%)
2022	90,000	43,500	4.5	1.8	-40% (Severe drought)	38% (-7%)
2023	92,000	44,000	7.8	2.7	+5% (Quality reduction)	45% (Normal)
2024*	88,000	42,000	5.0 (Estimated)	2.0 (Estimated)	-30% (Forecasted)	40% (Forecasted)

Source: Iași County Directorate for Agriculture (2024). Report on Agricultural Production (Note: Data for the 2024 annum constitute estimates/are provisional).

Repercussions of Aridic Conditions on Maize *(Zea mays)* Agronomy: In the 2022 agricultural cycle, the mean agronomic yield for maize (*Zea mays*) experienced a precipitous decline to 4.5 t/ha, a figure markedly divergent from the normative yields recorded in antecedent years (viz., 6.2 t/ha in 2020 and 7.1 t/ha in 2021). This substantial 40% diminution, relative to the established multiannual average, is unequivocally attributable to severe aridic episodes. Such considerable deficits in output are further compounded by a progressive contraction in the land area allocated to cultivation, diminishing from 95,000 hectares in 2020 to a nominal 88,000 hectares by 2024. The prognosis for the 2024 annum indicates an anticipated yield of 5.0 t/ha, representing a projected 30% reduction, thereby implying the persistence of unfavorable climatological conditions which serve to amplify the susceptibility of the local agrarian system.

The annum 2021 manifested as an agricultural period distinguished by pronounced anomalies in pluviometric regimes, which culminated in an erratic spatiotemporal dispersion of precipitation throughout the critical vegetative cycle. In April, recorded pluviometric inputs amounted to a nominal 32 mm, a figure markedly inferior to the multiannual normative value; this deficit consequently exerted a detrimental influence upon seed germination and the early ontogenetic stages of vernal cultivars. May, registering 51 mm, perpetuated this hydric insufficiency, whereas June afforded only a marginal amelioration with 95 mm of precipitation. Such acute temporal variability in rainfall is intrinsically linked to inconsistent pedohydric conditions, thereby predisposing cultivars like maize (*Zea mays*) and sunflower (*Helianthus annuus*) to the potential onset of intermittent hydric stress. Subsequently, August was characterized by a significant pluviometric deficit of 38 mm, indicative of a phase of edaphic aridity during the terminal stages of plant development.

Ephemeral Ameliorations and Attendant Limitations: The 2023 agricultural annum evidenced a discernible resurgence in agronomic output; maize (*Zea mays*) yields reached 7.8 t/ha (denoting a 5% augmentation), while sunflower (*Helianthus annuus*) production attained 2.7 t/ha, concurrently manifesting a normative oleaginous concentration of 45%. Such an amelioration, however, necessitates a circumspect assessment.

The observed quantitative enhancement in yield was reportedly achieved concomitantly with a "reduction in quality", a circumstance potentially indicative of persistent climatological disequilibria and the putative adoption of cultivars selected for enhanced resilience, possibly at the detriment of superior qualitative attributes.

A Discernible Retrenchment in Cultivated Acreage: The sustained diminution in land allocated to principal agricultural cultivars (notably maize (*Zea mays*) and sunflower (*Helianthus annuus*) is potentially indicative of a deliberate adaptive strategy implemented by agricultural producers. Confronted by recurrent pecuniary detriments, these producers may elect to curtail their agronomic operations or transition towards cultivating species possessing enhanced resilience to the adverse impacts of evolving climatic conditions. Such a phenomenon is poised to engender profound and far-reaching ramifications for the regional agrarian economy, thereby underscoring the exigent need for robust support mechanisms and a substantive agricultural paradigm transformation.

Data presented in the preceding table (Table 2) reveal an 18% diminution in maize (*Zea mays*) production for the year 2020; however, this figure encapsulates merely a fraction of the broader agricultural predicament. Commencing with the September 2020 harvest, it became conspicuously evident that the agricultural annum was severely compromised, with numerous municipalities experiencing complete yield failures for vernal cultivars such as maize (*Zea mays*) and sunflowers (*Helianthus annuus*) (DAJ Iași, 2022). In that same year, agricultural producers in Iași County submitted compensation claims pertaining to approximately 20,000 hectares of afflicted maize (*Zea mays*) and sunflower (*Helianthus annuus*) crops, constituting 14% of the total acreage dedicated to these commodities. Concurrently, autumn-sown crops, including wheat, barley, and rapeseed, accounted for roughly 34,000 affected hectares. The aridic conditions prevalent in 2020 significantly impacted 20% of the total arable land within Iași County, which encompasses 276,000 hectares. Analogous exigent circumstances were documented in the contiguous Moldovan and Dobrudgean counties, culminating in a cartographic depiction of widespread agricultural distress concentrated within the nation's eastern and southeastern territories (Serban and Maftei, 2025).

The estival period of 2022 was characterized by unprecedented xeric conditions, culminating in an unparalleled extent of cultivated land experiencing detrimental impacts. According to data collated by the Iași County Directorate for Agriculture (DAJ Iași), by August 2022, an area exceeding 112,000 hectares of agronomic land was officially documented as calamitous within the county. This figure encompassed approximately 42,000 hectares dedicated to autumn-sown cultivars from the 2021 cycle [predominantly *Triticum aestivum* (wheat) and *Brassica napus* (rapeseed)] and nearly 70,000 hectares of vernal cultivars [including *Zea mays* and *Helianthus annuus* (sunflower)], out of a total tilled expanse of 133,500 hectares (DAJ Iași, 2022). This significant datum represents circa 40% of the county's total arable land, underscoring the exceptional severity of the aridic episode.

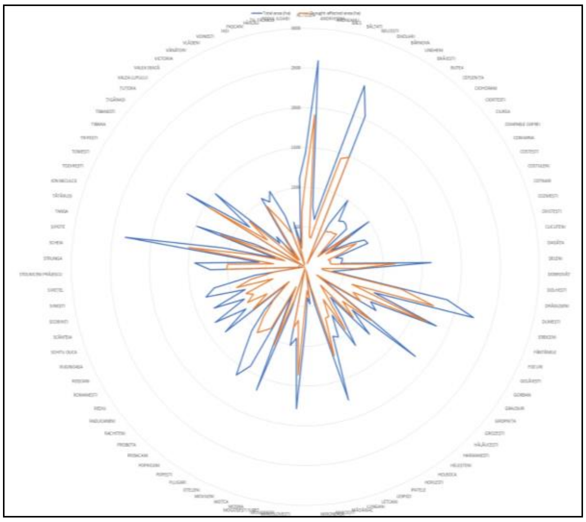
The empirical data delineated in Table 2 irrefutably substantiates an inverse correlation between the incidence of acute aridic episodes and the agronomic productivity of maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivars within the Iași County agrarian system. The temporal scope of this investigation furnishes a robust evidentiary basis for underscoring the imperative to formulate regionally-tailored agricultural strategies. Such strategies should, inter alia, integrate the following components: (i) the systematic deployment and optimization of comprehensive hydric management infrastructure; (ii) the concerted promotion and adoption of aridity-tolerant agronomic varieties; (iii) the provision of robust financial support mechanisms for agricultural producers, including dedicated agricultural insurance frameworks and climate-related risk mitigation funds; and (iv) strategic capital investment in infrastructure designed for pluvial water harvesting and long-term conservation.

Spatial Heterogeneity and Stratification of Drought Impact within Iași County. Figure 3 furnishes a radar chart visualization elucidating the subsequent key findings:

- Heterogeneity in Cultivated Acreage among Local Administrative Units (UATs): Significant divergences are observed in the extent of land under cultivation across Iași County's UATs. Select locales command over 2,500 hectares, whereas others comprise less than 500 hectares. Such variance is indicative of differential agronomic capacities and prevailing economic orientations, distinguishing between predominantly agrarian economies (e.g., Lunca Prutului) and those characterized by diversified or non-agrarian economic activities (notably within the peri-urban Iași metropolitan zone, including Miroslava, Valea Lupului, Bârnova, and Aroneanu).

- Magnitude of Agronomic Detriment Attributable to Protracted Aridity: In several documented instances, the extent of deleteriously affected agricultural land exhibits a strong positive correlation with the total area under cultivation. This observation suggests both the acute intensity of the aridic episode within these specific regions and a potential paucity of robust protective or mitigative measures against sustained hydric deficits or the sheer severity of the drought event itself. This congruence, as visually represented, implies an inherent systemic vulnerability, particularly in UATs where agricultural practices are primarily reliant upon pluvial water sources.

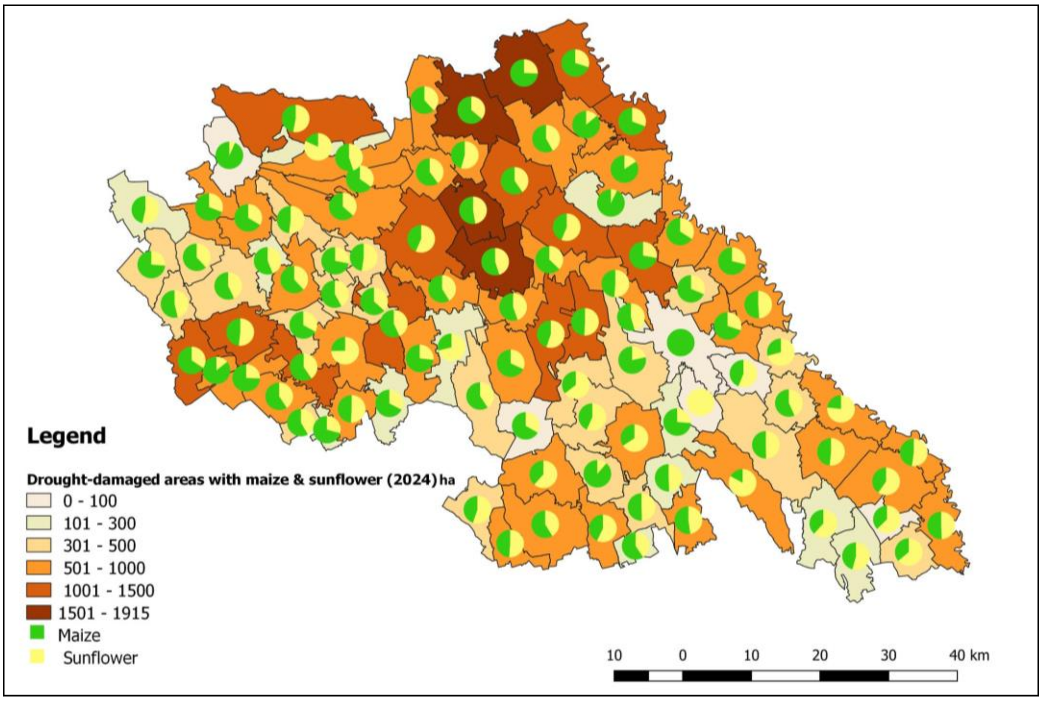
- Identification of Critically Affected Administrative Units: The UATs of Andrieșeni, Focuri, Șipote, and Țigănași demonstrate an exceptionally pronounced magnitude of agricultural damage, wherein the drought-impacted acreage is almost coextensive with the total land area farmed. These specific micro-regions constitute focal areas of heightened agro-climatological risk within Iași County. Consequently, they warrant preferential consideration in the formulation of climate resilience strategies and the implementation of pilot initiatives for adaptive agricultural technologies.



Source: Own computations.

Figure 3. Comparative Geospatial Analysis/Juxtaposition of Cultivated Areas [Maize (*Zea mays*), Sunflower (*Helianthus annuus*)]: Maize (*Zea mays*) and Sunflower (*Helianthus annuus*) Cultivation Acreage versus Drought-Affected Areas within Iași County Administrative Units (2024)

A geospatial assessment of the repercussions of the 2024 aridic episode on maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivars, delineated in Figure 4, reveals extensive deleterious impacts pervading the entirety of Iași County's administrative jurisdiction. Locales manifesting heightened vulnerability were predominantly identified within the northeastern, central-eastern, and occidental sectors of the county, in conjunction with the Lunca Prutului depressionary zone. In these areas, indices reflecting severe agricultural distress exhibited markedly elevated magnitudes.



Source: Own computations.

Figure 4. Geospatial Delineation of Drought-Induced Detriment to Maize (*Zea mays*) and Sunflower (*Helianthus annuus*) Cultivars within Iași County Administrative Units (2024)

Conversely, locales positioned within the immediate southern environs of Iași municipality and the north-occidental sector of the county exhibited comparatively attenuated agricultural detriments, signifying a more constrained scope of adverse impact upon the cultivars under investigation.

Within the administrative-territorial unit (ATU) framework, it is conspicuously evident, with minimal exceptions, that regions dedicated to maize (*Zea mays*) cultivation were subjected to a more pronounced detrimental impact compared to those areas allocated for sunflower agronomy. This differential in impact severity can be elucidated through a bifurcated perspective: firstly, the potentially superior resilience of extant sunflower hybrids to conditions of acute hydric stress; and secondly, a marginally more propitious spatiotemporal distribution of pluviometric inputs-in terms of both volumetric accumulation and timely occurrence - coinciding with the critical ontogenetic stages of sunflower (*Helianthus annuus*) development.

Administrative-Territorial Units (ATUs) manifesting the most profound agricultural detriment, wherein compromised cultivated areas exceeded 1,500 hectares per unit, were principally identified within the communes of Erbiceni, Andrieșeni, Focuri, and Șipote, indicative of acute repercussions for the agrarian sector in these specific locales. A secondary stratum of considerable agronomic damage, characterized by affected expanses surpassing 1,000 hectares per ATU, was documented across the communes of Bivolari, Dumești, Gropnița, Lețcani, Miroslovești, Movilă, Șipote (noted for extensive impact across multiple damage categories), and Trifești. Furthermore, a tertiary category involving significant, albeit less uniformly quantified, impacted agricultural acreages per ATU was recorded in a broader range of communes, including Deleni, Movileni, Popești, Popricani, and Stolniceni-Prăjescu, alongside several of those previously enumerated. This distribution underscores a pronounced spatial agglomeration of agro-climatological vulnerabilities, particularly concentrated within the boreal and medial sectors of the county.

The Administrative-Territorial Units (ATUs) encompassing Focuri, Răchiteni, Dobrovăț, Ciurea, Costuleni, Mircești, Ungheni, Stolniceni-Prăjescu, Valea Seacă, Comarna, and Bârnova were subjected to the most acute levels of agricultural detriment. Within these specific communes, the compromised acreage dedicated to maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivation exceeded an 80% threshold. Consequently, these aforementioned ATUs demonstrate a pronounced degree of agrarian susceptibility, which directly impinges upon localized agronomic productivity and perturbs the socio-economic equilibrium of the attendant rural communities.

Analysis of Agrometeorological Impacts on Agricultural Production Metrics

Deficiencies in pluviometric input during pivotal phenological periods for maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivation exert a direct and adverse influence upon key indices of agronomic output. Furthermore, extant scholarly findings indicate that a rigorous appraisal of regional agro-climatological potential mandates an exhaustive investigation into ambient thermal regimes and available hydric endowments, in conjunction with an analysis of plant-available water reserves throughout disparate pedological horizons.

Extended drought significantly impacts maize (*Zea mays*) harvests, as the period from April to August represents peak water usage. Inadequate water supply prompts plants to develop physiological adaptations for water conservation, adversely affecting total biomass and grain yield.

Notwithstanding their general characterization as a drought-resilient agronomic species (a trait particularly pronounced in hybrid varieties), *Helianthus annuus* (sunflower) can nevertheless exhibit significant diminutions in oleaginous concentration and capitulum dimensions when subjected to protracted hydric deficits during the critical ontogenetic stages of anthesis and seed maturation, consequently compromising both the qualitative attributes and volumetric yield of the harvest.

The scrutinized stacked area graphical representation elucidates a protracted aridic episode in 2024, characterized by deficient pluviometric inputs during the critical vegetative period for maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivars. Furthermore, the heterogeneous intra-annual dispersion of these pluviometric inputs, wherein augmented volumes were predominantly concentrated within September, proved insufficient to ameliorate the accrued hydric shortfall experienced throughout pivotal phenological intervals indispensable for optimal phytological development.

The discerned geospatial heterogeneity across the network of nine meteorological observatories underscores the imperative for implementing bespoke agronomic management protocols, meticulously harmonized with specific localized pluviometric regimes. Furthermore, rigorous monitoring of pedohydric conditions, coupled with the systematic adoption of technologies engineered for hydric resource optimization, constitute pivotal strategies to ameliorate the adverse repercussions of aridic episodes upon agricultural productivity, particularly within the context of ongoing climatic shifts.

The elucidated empirical results underscore the exigent need for recalibrating agronomic timelines and optimizing cultivar selection in strict congruence with prevailing regional climatological regimes. Concurrently, these findings affirm the critical imperative to institute efficacious hydric management infrastructure, designed to ameliorate deficits in natural pluviometric input during pivotal ontogenetic stages of crop maturation.

Overarching Synthesis of Drought Impacts

The extant irrigation infrastructure demonstrably ameliorated the agricultural detriment engendered by the 2024 aridic episode. Notwithstanding this, a nominal 15% of the county's total cultivated acreage currently derives benefit from such hydric management systems. Consequently, in locales devoid of this essential infrastructure, rain-fed agrarian territories remained exclusively reliant upon natural pluviometric inputs, a situation that underscores significant disparities in adaptive capacity and resource accessibility among the constituent municipalities.

Pertaining to maize (*Zea mays*) agronomy, it is imperative to underscore that within administrative-territorial units (ATUs) devoid of requisite irrigation infrastructure (exemplified by Holboca and Rediu), agronomic yields experienced a substantial diminution of 50-70%. Concomitantly, acute thermal duress within these locales precipitated suboptimal plant ontogeny, manifesting as anomalous caryopsis morphology and a terminal grain moisture content registering below 12% at harvest. Conversely, in those ATUs possessing functional irrigation systems (such as Popricani and Erbiceni), yields demonstrated an augmentation of 20-30%; this enhancement, however, was paralleled by a considerable escalation in operational cultivation expenditures.

Helianthus annuus (sunflower) cultivars manifested compromised florescence, a condition attributable to deficient pluviometric inputs during the critical June-July period requisite for achene maturation. Consequently, rain-fed agricultural zones (exemplified by Victoria and Gorban) recorded diminutions in agronomic output ranging from 40% to 60%; this stands in marked contradistinction to yield outcomes observed in irrigated counterpart locales such as Vlădeni.

Through a correlative analysis juxtaposing drought-impacted territories within Iași County with prevailing pluviometric regimes and regional patterns of hydric resource utilization, zones of agronomic production are subsequently stratified into four discrete categories:

- **Category I: Locales Exhibiting Negligible Drought Impact:** These administrative-territorial units (ATUs) experienced minimal adverse effects, a circumstance primarily attributed to the incidence of more substantial, albeit spatially circumscribed, pluviometric inputs (ranging from 250-300 mm) during critical phenological stages. Projected diminutions in agronomic output for these areas were estimated at less than 20% for maize (*Zea mays*) and below 15% for sunflower (*Helianthus annuus*) cultivation. This classificatory group encompasses the communes of Lețcani, Belcești, and Popricani.
- **Category II: Administrative-Territorial Units (ATUs) Manifesting Moderate Agronomic Detriment:** These locales are distinguished by pluviometric inputs substantially inferior to long-term normative values (specifically, under 200 mm during the critical June-July timeframe) and are further characterized by argillaceous soil compositions exhibiting limited hydric retention capabilities. Within such ATUs (exemplified by Miroslava, Șipote, and Dănești), recorded yield deficits for *Zea mays* (maize) fluctuated between 30% and 40%, whereas diminutions in *Helianthus annuus* (sunflower) productivity were observed in the 35% to 50% range.
- **Category III: Administrative-Territorial Units (ATUs) with Compounded Agro-Environmental Vulnerabilities:** This classification pertains to locales characterized by inherently susceptible agricultural zones, a deficiency in requisite irrigation infrastructure, discernible pedological degradation, and a pronounced dependency on natural pluviometric inputs. Within such ATUs (exemplified by Holboca, Rediu, and Aroneanu), pluviometric inputs during the critical anthesis phase of *Helianthus annuus* (sunflower) cultivations were recorded at levels inferior to 150 mm. This deficit precipitated substantial yield diminutions, ranging from 50% to 70%, for both principal agricultural cultivars maize (*Zea mays*) and sunflower (*Helianthus annuus*).
- **Category IV: Administrative-Territorial Units (ATUs) Experiencing Extreme Drought Impact under Non-Irrigated Conditions**: This category comprises locales subjected to acute aridic stress, characterized by pluviometric inputs registering below 100 mm during pivotal phenological periods, and concurrently lacking any established irrigation infrastructure. Within such critically affected ATUs (exemplified by Vlădeni, Tomești, and Gorban), resultant diminutions in agronomic output for *Helianthus annuus* (sunflower) cultivation surpassed an

80% threshold, while yield deficits for *Zea mays* (maize) were recorded in excess of 60%.

A comprehensive synthesis of the 2024 empirical datasets demonstrates that the magnitude of detriment experienced by maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivars exhibits an explicit correlation with the synergistic effects of suboptimal irrigation regimes and deficient pluviometric inputs.

CONCLUSIONS

Protracted agricultural hydric stress constitutes a substantial and progressively intensifying impediment to the viability of the agro-alimentary sector, discernible at both global and regional echelons. This assertion is empirically substantiated by data pertaining to maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivation within the specific case study of Iași County.

The present analysis elucidates that the augmented frequency and intensification of aridic episodes have precipitated a concatenation of repercussions across diverse socio-economic and operational strata. The diminution in agronomic yields has engendered substantial pecuniary detriments, perturbed market equilibria, compromised the emoluments of agricultural producers, and incurred significant social costs attributable to the amplified vulnerability of rural communities. Notwithstanding these conspicuous ramifications, recent drought events within Iași County (viz., 2020, 2022, 2024), paralleling observations in other Romanian territories, have accentuated an inordinate dependency on natural pluviometric inputs, the suboptimal progression of irrigation infrastructure development, and, of paramount critical concern, the constrained fiscal capacity of smallholder agriculturalists to effectively navigate such pervasive environmental incertitudes.

The present analysis unequivocally delineates the pronounced divergence between irrigated agrarian zones and those exclusively reliant upon pluvial conditions, thereby accentuating the considerable agricultural detriment documented within the county's austral administrative units. Furthermore, the 2024 aridic episode brought into sharp relief the inherent vulnerability of conventional agronomic systems to prevailing climatic shifts, mandating the implementation of sustained, localized ameliorative strategies. Episodes of acute and protracted hydric deficit have demonstrably compromised both principal crops under evaluation [namely, maize (*Zea mays*) and sunflower (*Helianthus annuus*)], precipitating significant diminutions in both volumetric output and qualitative attributes throughout the observation period encompassing 2020, 2022, and the prospective 2024 annum.

Relative to *Helianthus annuus* (sunflower), *Zea mays* (maize) demonstrates a markedly heightened vulnerability to aridic stress, with its agronomic productivity susceptible to negative oscillations of as much as 40%. In contrast, *Helianthus annuus* (sunflower) exhibits a maximal yield diminution of 30% in terms of volumetric output. Furthermore, the oil concentration within sunflower achenes functions as a highly responsive proxy for abiotic stress. This concentration has been observed to oscillate between 38% and 45% during the period under review, a variability that directly impinges upon the commercial viability of the derived oleaginous product within the agri-processing sector.

Absent the systematic implementation of multifaceted adaptive strategies - encompassing the modernization of hydric management infrastructure, targeted genetic amelioration for enhanced drought resilience in cultivars, adherence to scientifically informed rotational cropping systems, and the adoption of conservative agronomic principles - it is anticipated that the pecuniary detriments attributable to recurrent aridic episodes will undergo sustained intensification within Iași County and comparable planitian zones of the broader Moldovan territory.

Managing and adapting to arid conditions must become an essential component of national agricultural policy, for which we propose the following necessary actions:

– a systematic evaluation of drought susceptibility and nascent climatic shifts, achieved through the integrated analysis of contemporary (e.g., 2024) and multiannual climatological datasets. The objective is to discern recurrent patterns and thereby inform the formulation of proactive, anticipatory strategies.

- the strategic prioritization of climate change adaptation initiatives, encompassing inter alia: the deployment and optimization of hydric management infrastructure (irrigation systems); the selection and propagation of aridity-tolerant maize (*Zea mays*) and sunflower (*Helianthus annuus*) cultivars; and the widespread adoption of resource-efficient, sustainable agronomic paradigms. Such initiatives are to be concentrated particularly within administrative-territorial units (ATUs) recurrently subjected to significant deleterious impacts from aridic episodes.

- the strategic application of large-scale datasets and advanced analytical methodologies to formulate a cohesive, integrated county-level strategy for climatological risk governance. Such a strategy must necessarily encompass both preemptive mitigation protocols and efficacious systems for indemnity and stakeholder support. The successful actualization of this comprehensive plan is contingent upon synergistic, multi-stakeholder collaboration - involving research and academic institutions, the County Agricultural Directorate, community-based action consortia (e.g., Local Action Groups), municipal administrative bodies (ATUs), pertinent agricultural associations, cooperatives, producer organizations, and broader civil society representation - all predicated upon a robust participatory governance framework.

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