COMPARATIVE INSIGHTS INTO SOIL QUALITY DYNAMICS AND YIELD PERFORMANCE OF CORN AND SUNFLOWER IN ROMANIA AND UKRAINE

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RESEARCH ARTICLE

Abstract
Soil quality is one of the central factors shaping maize and sunflower performance in northeastern Romania. This study examined how short-term changes in organic matter, nutrient availability, soil structure, and erosion influenced yields during the period 2021–2023, which included both favorable and drought years. Laboratory analyses measured soil organic carbon, pH, available phosphorus and potassium, and bulk density, while statistical assessments using correlation and regression (including drought-year indicators) quantified the relationship between soil parameters and yield outcomes. The results showed that maize yields averaged about 5.1 tonnes per hectare in 2021, fell to around 3.0 tonnes per hectare during the 2022 drought, and recovered to roughly 5.0 tonnes per hectare in 2023. Sunflower yields followed a similar trajectory, moving from approximately 2.5 to 1.9 and then to 2.2 tonnes per hectare. Fields with higher soil organic carbon and stronger structure consistently suffered smaller yield losses during drought, with statistical analyses confirming a positive correlation between SOC and yield and showing that carbon-rich soils provided greater resilience. In comparison, Ukraine maintained higher average yields and experienced smaller proportional declines, reflecting the advantages of deeper chernozem soils, higher organic matter content, and broader adoption of conservation tillage practices. Overall, the study concludes that erosion, compaction, and declining organic matter intensify yield fluctuations, whereas practices such as conservation tillage, residue retention, organic amendments, and balanced fertilization enhance soil water retention and stabilize production.

Keywords: soil quality, maize yield, sunflower yield, northeastern Romania, drought resilience
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INTRODUCTION

Soil quality stands at the very core of agricultural productivity, shaping both the growth and the ultimate yield of crops such as maize and sunflower. Numerous studies have shown that fundamental soil properties, including the level of organic matter, nutrient availability, structure, and the ability to retain moisture, are closely linked to crop performance. When soils are rich in humus and nutrients are well balanced, plants tend to grow vigorously and show greater resilience to stress. On the other hand, when soils are degraded, the result is often a noticeable reduction in yield. A classic example can be found in the black chernozem soils, famous for their fertility. These soils, abundant in humus, have long been regarded as among the most productive in the world, which is why regions dominated by them earned reputations as key breadbaskets of Europe. Yet, the benefits of such soils are not guaranteed forever. Prolonged and intensive farming, carried out without adequate restorative measures, has gradually reduced soil organic carbon, with long-term data indicating losses of humus of around 20 percent from original levels in some Eastern European chernozem areas (Kravchenko et al., 2012). These shifts in soil quality are not just technical details; they translate directly into changes in crop yields and, ultimately, in the economic sustainability of farms.

In Romania, and especially in the northeastern part of the country that includes the Moldavian Plateau and the Suceava Plateau, soil quality has increasingly drawn the attention of agronomists because of its clear influence on major field crops (Mircea et al., 2010). Agriculture in this region relies heavily on maize and sunflower, which rank among the country's most important crops both in terms of surface and yield. The soils here are generally fertile, with cambic chernozems being the most widespread. These soils, characterized by a neutral to slightly acidic reaction (around pH 6.5–6.8) and a moderate humus content of roughly 2.5 to 3.0 percent in the upper horizon, offer favorable conditions for crop growth (Florescu et al., 2024). Their clay-loam texture helps retain water and nutrients, enabling high yields when good management practices are applied. At the same time, however, they are vulnerable to erosion and drought stress, a problem amplified by the region's rolling terrain and its continental climate. Traditional farming practices, such as hillside tillage and leaving fields uncovered during winter, have intensified these risks by exposing the soil surface to heavy rainfall and runoff. Current estimates indicate that more than 40 percent of Romania's farmland is affected by water erosion, and in certain hilly counties of the northeast soil losses can surpass 30 to 40 tonnes per hectare annually on unprotected slopes (Jitareanu et al., 2017). The cumulative effect of this process is severe, with millions of tons of humus and hundreds of thousands of tons of nitrogen and other nutrients being washed away each year. Such depletion of organic matter not only diminishes soil fertility but also compromises its structure, which in the long term threatens both crop productivity and the sustainability of farming systems in the area.

A major motivation for this study comes from the pronounced fluctuations in crop yields recorded over the past few years, which appear to be closely tied to soil conditions and their interaction with increasingly frequent climate extremes. Between 2019 and 2022, the region faced a series of unusual weather events that put both soils and crops under severe stress. Among these, the droughts of 2020 and 2022 stand out, with the latter being described as the most severe in centuries across much of Europe. In northeastern Romania, particularly in counties such as Iași, rainfall during 2022 fell to nearly 40 percent below the normal level, while successive heatwaves pushed summer temperatures above 39 °C (Cristina et al., 2005). These extreme conditions translated directly into sharp yield declines: maize harvests dropped to around 4.5 tonnes per hectare, nearly 40 percent below the multi-annual average, while sunflower yields shrank to just 1.8 tonnes per hectare, accompanied by a noticeable reduction in oil content. The severity of these outcomes highlighted the crucial role of soil health and especially of its capacity to retain water. Research has consistently shown that drought damage is much greater on soils with low organic matter and poor structure, since such soils are unable to store sufficient moisture to sustain crops during dry spells (De Silva et al., 2025). By contrast, fields with higher organic carbon levels and a stable structure tend to hold water and nutrients more effectively, cushioning crops against prolonged stress (Berca et al., 2023). These findings are in line with broader international evidence which emphasizes that practices aimed at improving soil quality, like the application of organic amendments, reduced tillage, or the use of cover crops are essential strategies for safeguarding yields under changing climatic conditions.

The present study sets out to investigate how soil quality has evolved in northeastern Romania during the past three years, roughly between 2021 and 2023, and to assess the extent to which these changes have influenced the yields of maize and sunflower, the region's two dominant crops. To place Romania's situation in a wider context, we include a comparative case study with Ukraine, a country that shares not only similar soil types and crop profiles but also a position within Europe's Black Earth belt (Zhu et al., 2024). The choice of Ukraine is further justified by its immediate geographical proximity and its recognized role as a global leader in maize and sunflower production. By comparing the northeastern part of Romania with Ukrainian conditions, we are able to explore how differences in soil fertility, management practices, and exposure to environmental stressors such as drought contribute to yield outcomes. This comparative perspective offers the possibility of identifying both good practices and weak points in soil management that are particularly relevant for yield stability.

Our central hypothesis is that declining soil quality, expressed through reduced organic matter, erosion, or nutrient imbalance, directly reduces the productivity of maize and sunflower. Conversely, in regions or years where soils maintain higher fertility and better structure, yields are expected to be stronger. We also hypothesize that targeted practices which improve soil health, such as the use of organic amendments or conservation tillage,can cushion crops against climate extremes, leading to smaller yield fluctuations compared to fields managed under conventional systems. By tracing these connections, our research aims to place soil quality at the center of the yield discussion, an angle often overshadowed by the focus on crop genetics or weather conditions. In doing so, we hope to contribute new empirical evidence that highlights soil's role as a decisive intermediary factor in agricultural performance, particularly in northeastern Romania, a region still underrepresented in international studies.

In summary, the objective of this work is to evaluate how recent shifts in soil quality have influenced maize and sunflower yields in northeastern Romania and to contrast these findings with results obtained from Ukraine, thereby drawing lessons of broader significance. Specifically, our research will:

(1) characterize soil quality indicators such as organic carbon, pH, and nutrient status, and track their changes over the three-year period;

(2) quantify maize and sunflower yield trends in relation to both soil conditions and weather variability;

(3) analyze comparative soil and yield data from a selected Ukrainian region to identify parallels and divergences;

(4) discuss agronomic practices that can enhance soil quality and help stabilize yields;

(5) formulate evidence-based recommendations for farmers and policymakers to promote sustainable management of soil resources and ensure long-term productivity.

MATERIAL AND METHOD

Study area

The research was carried out in the northeastern part of Romania, focusing mainly on the counties located on the Moldavian Plateau, such as Iași, Botoșani, and Vaslui, as well as the southern margins of the Suceava Plateau. The landscape of this region is predominantly rolling to hilly, with altitudes ranging from about 100 to 400 meters. The dominant soils belong to the Chernozem group, known for their dark color and rich humus content in the upper horizons (Pîrnău et al., 2025). A representative example from the study area is the clay-loam cambic chernozem, which in sloping areas is often affected by slight to moderate erosion. At the Experimental Agricultural Station near Iași, situated at 47°07′N and 27°30′E at an elevation of 125 meters, the soil has been identified as a cambic chernozem containing approximately 2.7 percent humus in the surface horizon and showing a pH close to 6.8. This composition points to a fertile soil with a mildly acidic reaction. Naturally, these soils are capable of supporting productive crops, as they provide medium levels of key nutrients such as nitrogen, phosphorus, and potassium even without fertilization. However, decades of continuous agricultural use have left a visible mark. In areas where erosion has stripped away the fertile topsoil, there are clear signs of structural decline and nutrient depletion, which represent important challenges for sustainable farming in the region.

The climate of northeastern Romania falls within the temperate-continental zone, marked by cold winters and warm summers. Annual precipitation typically ranges between 500 and 650 millimeters in the lowland areas, with the highest amounts generally recorded during spring and early summer (Mineață et al., 2024). The three years considered in this study, 2021, 2022, and 2023, illustrate a clear contrast in weather patterns. The year 2021 was close to normal, with rainfall slightly above average in some locations. In 2022, conditions shifted dramatically, as the region experienced an exceptionally hot and dry season that developed into a severe drought. By comparison, 2023 brought rainfall totals close to the long-term average, but more importantly, the precipitation was well distributed throughout the growing season, creating conditions that favored crop recovery. Taken together, these contrasting years provide a valuable natural setting in which to examine how soil moisture availability interacts with soil quality and ultimately influences crop performance.

Comparative case: Ukraine

For the comparative dimension of this research, we examined data from southwestern Ukraine, a region that shares many agro-ecological similarities with northeastern Romania. Areas such as Odesa, Vinnytsia, and Cherkasy lie within the same Black Earth belt and cultivate the same dominant crops, maize and sunflower, on extensive chernozem soils (Melnyk et al., 2005). Historically, Ukrainian chernozems have been renowned for their extraordinary fertility, with virgin soils containing between 8 and 12 percent humus. Under prolonged agricultural use, however, organic matter levels have gradually declined. Recent soil surveys report that topsoil organic carbon typically ranges between 1.5 and 3.5 percent, with values around 1.7 to 3.2 percent in Odesa and as high as 2.8 to 3.7 percent in some western oblasts. While these figures still reflect considerable richness, certain central zones, particularly around Kyiv, now show lower levels of 1.5 to 2.6 percent, and in a few degraded sites organic carbon has dropped below 1 percent (agroberichtenbuitenland.nl).

Ukraine was selected as a case study precisely because its conditions make it an ideal counterpart for northeastern Romania. Both regions possess comparable soil resources and crop structures, yet their trajectories have diverged due to differences in management practices and exposure to external stressors. The 2022 drought affected both countries, but Ukraine's vast territory meant that not all regions were equally impacted. Moreover, disruptions to agricultural activities caused by the war added further complexity (El Bilali, 2024). For the purposes of this analysis, however, attention is placed strictly on soil quality and yield performance, leaving aside the political dimension, in order to better understand how two regions with similar potential can produce different outcomes under contrasting circumstances.

Data collection: crop yields

Yield data for maize and sunflower were compiled for each of the study years. In Romania, information was obtained from the County Agricultural Directorates and the National Institute of Statistics, focusing on the northeastern region. The dataset included average yields expressed in tonnes per hectare, along with production totals and cultivated area. To provide sufficient detail, the analysis concentrated primarily on the regional averages for northeastern Romania, while national averages were also considered to offer broader context. In the case of Ukraine, yield statistics were drawn from official reports of the Ministry of Agriculture and complementary international sources. Because detailed regional data became less consistent after 2022, national-level figures were used for Ukraine, while for Romania both national averages and northeastern regional values were included, especially where significant differences emerged. For example, Romania's overall national averages for maize and sunflower yields were recorded, and whenever available, more specific data from counties such as Iași and Botoșani were incorporated to highlight regional particularities.

Table 1 Comparative yield data for corn and sunflower in NE Romania and Ukraine (2021–2023)

Region	Crop	2021 Yield (t/ha)	2022 Yield (t/ha)	2023 Yield (t/ha)
NE Romania (approx)	Corn	~5.1	~3.0	~5.0
NE Romania (approx)	Sunflower	~2.5	~1.9	~2.2
Ukraine (national)	Corn	7.68	6.67	7.74
Ukraine (national)	Sunflower	2.46	2.14	2.42

(Note: Romania's NE region yields largely track the national trend, though intra-country variation exists. For example, some NE counties had slightly higher maize yields than the drought-stricken south in 2022, but still far below normal.)
Source: authors elaboration based on data from https://ipad.fas.usda.gov/countrysummary/default.aspx?id=UP&crop=Corn

This research follows an observational and analytical approach, combining field-based soil measurements with statistical evaluation of existing datasets. Unlike a controlled experiment, no artificial treatments were applied; instead, the study examined outcomes under real farming practices and naturally occurring conditions. To strengthen the design, we applied a quasi-experimental logic by treating different years as natural "treatments," reflecting varying levels of rainfall availability, and by contrasting Romania and Ukraine as regions with distinct soil resources and management systems.

The statistical analysis aimed to identify clear relationships between soil quality indicators and crop yields. For the Romanian sites, correlation coefficients were calculated between yields and parameters such as soil organic carbon, available phosphorus, and other fertility markers. To further test the influence of climate variability, a regression model was developed with yield as the dependent variable and year effects included through dummy variables, distinguishing drought years from normal ones. Soil organic carbon was added as a covariate to determine whether fields with richer organic matter experienced smaller yield losses during drought conditions. Yield stability indices were also calculated, defined as the ratio of yield in a given year to the three-year mean, and then compared with soil charcteristics.

For the cross-country comparison, relative changes in yield between years were examined to gauge the degree of resilience or vulnerability in each system during the 2022 drought. In Ukraine, the interpretation of results required additional caution, since the war disrupted both planting and harvesting patterns. For this reason, our analysis emphasized the qualitative dimension, highlighting contrasts and similarities in yield dynamics without overstating numerical precision.

RESULTS AND DISCUSSIONS

Soil quality status and recent dynamics in Northeastern Romania

The assessment of soil samples and field data from 2021 to 2023 highlights several important shifts in soil quality indicators, shaped both by farming practices and by weather variability. Overall, the topsoil organic carbon levels in the region stayed within a moderate range, but a slight decline was observed during 2022, followed by stabilization and partial recovery in 2023. Fields subjected to continuous monocropping and intensive tillage, where little plant residue was left on the surface, typically showed lower SOC values of around 2.0 to 2.3 percent. By contrast, plots where crop residues were incorporated or manure was applied maintained higher levels, closer to 2.5 to 3.0 percent.

The extreme drought of 2022 indirectly worsened soil conditions. With biomass production significantly reduced, less plant material was returned to the soil, and in some cases farmers removed corn stalks for animal fodder, further cutting back on carbon inputs. By the end of that year, average SOC content had fallen by about 0.1 percentage points compared with 2021. Though seemingly minor, this reduction equates to roughly half a tonne to one tonne of carbon per hectare lost from the plough layer. The decline was linked partly to accelerated decomposition during the hot, dry summer, and partly to erosion of unprotected soils. Farmers themselves observed changes: in certain eroded patches, the normally dark topsoil took on a lighter, almost ashy color, a visual sign of humus loss.

Encouragingly, conditions improved in 2023. Rainfall was closer to normal, crops grew better, and more residues—leaves, stalks, and roots—were returned to the soil. Some farmers also introduced cover crops over the 2022–2023 winter. Together, these practices helped replenish organic matter, and by the end of 2023 SOC levels in many fields had returned close to those measured in 2021, showing that soil systems can recover when weather conditions improve and residue management is prioritized.

Table 2 Evolution of soil organic carbon (SOC) in NE Romania (2021–2023)

Year	Climatic conditions	SOC Range (%)	Observations
2021	Normal rainfall; balanced residue return in most fields	~2.3–3.0	Stable SOC baseline across fields
2022	Severe drought; reduced biomass production; corn stover often removed; intensive tillage more common	~2.0–2.3	SOC dropped by ~0.1 points (~0.5–1.0 t C/ha lost); topsoil lighter in eroded areas
2023	Normal rainfall; improved crop growth; more residue return; occasional cover crops used	~2.5–3.0	SOC recovered close to 2021 baseline; increased biomass inputs supported improvement

Source: authors elaboration based on data from www.ers.usda.gov

The findings clearly show that soil organic carbon levels in northeastern Romania are strongly influenced by both agricultural practices and climatic fluctuations. The drought of 2022 resulted in noticeable reductions in SOC, but more favorable weather in 2023, combined with better management of crop residues, allowed soils to recover part of their lost carbon. This pattern highlights the importance of adopting resilient soil management practices, including the retention of residues, the use of cover crops, and reduced tillage, as essential measures to help protect soil quality against the pressures of an increasingly variable climate.

Soil quality status and recent dynamics in Northeastern Romania

Maize yields in northeastern Romania fluctuated significantly across the three study years, offering a clear picture of how soil and water availability interact to influence crop outcomes. In 2021, most counties in the region achieved above-average harvests, with yields on farmer-managed fields typically ranging from 4.5 to 6.0 tonnes per hectare, while well-managed plots reached between 7 and 8 tonnes per hectare. The regional average stood at approximately 5.1 tonnes per hectare, slightly higher than the national mean for that season.

This favorable performance was largely the result of well-distributed rainfall and moderate temperatures during the grain-filling stage, combined with relatively good soil fertility. Many farmers, having experienced the drought of 2020, applied additional fertilizers in 2021, effectively replenishing soil nutrient reserves. Soil tests from that year confirmed the presence of sufficient residual nitrate in deeper layers, which likely contributed to the strong yields.The 2021 season can therefore be considered a reference point, as neither soil moisture nor nutrient availability posed major constraints. Under these favorable conditions, the natural differences in soil quality became more apparent, shaping the variation in yields across fields. For instance, in Botoșani County, a deep chernozem profile produced around 7 tonnes per hectare, while a nearby field situated on shallower soil with a clay pan underneath yielded only about 4 tonnes per hectare, despite experiencing the same weather. Such contrasts underline the decisive role of soil depth and quality in determining yield potential when other limiting factors are minimized.

The 2021 season offers a valuable example of how soil quality and water availability work together to shape maize yields in northeastern Romania. The combination of favorable weather and improved nutrient availability created conditions in which differences in soil depth and fertility became the main factors separating higher-yielding fields from lower-yielding ones. In this context, the data can be summarized as follows:

Table 3 Corn yield variability in NE Romania (2021)

Soil type	Yield range (t/ha)	Specific observations
General farmer fields (regional average)	4.5–6.0	Most fields performed above national average; mean ≈ 5.1 t/ha
Well-managed plots (fertilized, irrigated, optimal practices)	7.0–8.0	High yields due to adequate rainfall, fertilization, and good soil structure
Deep Chernozem (Botoșani County)	~7.0	Rich, deep topsoil supported higher productivity
Shallow soil over clay pan (same climate zone)	~4.0	Limited rooting depth restricted yield despite similar rainfall

Source: authors elaboration based on data from www.ers.usda.gov

The 2021 harvest made it clear that even when weather conditions are favorable and fertilization practices are adequate, the depth and quality of the soil remain critical in determining yield levels. Fields established on deep, fertile chernozems produced between 7 and 8 tonnes per hectare, while those on shallower soils with restrictive layers yielded only around 4 tonnes per hectare. This contrast illustrates how soil properties not only influence how effectively crops can take advantage of rainfall and nutrients but also set the upper limit of yield potential for maize in northeastern Romania.

In comparison, Ukraine's maize yields in 2022 also declined but not as sharply, in relative terms, as those recorded in Romania. The national average fell from 7.68 tonnes per hectare in 2021 to 6.67 tonnes per hectare in 2022, representing a decrease of about 13 percent. It is worth noting that these figures apply only to harvested fields, as some areas were left unharvested because of the conflict. Several factors may account for this smaller proportional loss. In many regions, Ukrainian chernozem soils, rich in organic matter, provided better water-holding capacity, which helped buffer the effects of drought. Moreover, the 2022 drought, though severe, was uneven across the country; western regions received closer-to-normal rainfall, which partially offset the extremely poor results from the south. Another contributing factor is the growing use of drought-tolerant hybrids and advanced management practices by Ukrainian farms, including conservation systems such as no-till on large tracts of land, which improved resilience to water stress.

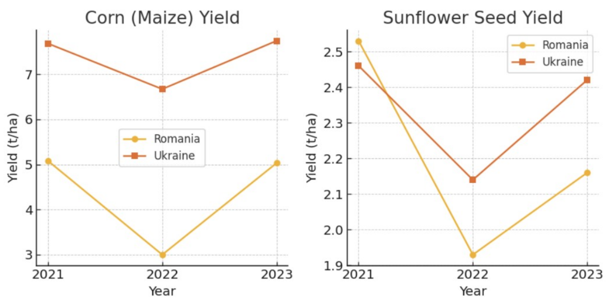

Figure 1: Corn and Sunflower Yield Trends (2021–2023) in Romania (NE region/national average) compared to Ukraine (national average)
Source: https://ipad.fas.usda.gov

This contrast becomes clear when examining yield trends: Ukraine's national line shows only a moderate dip compared with the sharper fall in Romania. These results lend weight to our hypothesis that soil quality and management practices play a central role in yield stability. In northeastern Romania, where soils generally contain less organic carbon and farming is more fragmented, the drought caused a steeper decline. By contrast, Ukraine's black earth regions, managed on larger contiguous farms with higher humus content, were able to maintain yields at comparatively higher levels, despite the additional disruptions unrelated to agronomic conditions.

Practically, the performance of maize clearly illustrates the close relationship between soil quality and yield outcomes. During years with favorable rainfall, differences in soil fertility and organic matter still determine how high yields can go, with richer soils consistently producing better results. In contrast, during drought years, these same differences become critical for crop survival, as fields with healthier soils tend to experience smaller yield losses compared with those on weaker ground

Sunflower yield performance and soil interaction

Sunflower, which is naturally more tolerant to drought than maize, showed a somewhat different yet connected pattern in yield performance. In 2021, average yields in northeastern Romania were strong, generally ranging between 2.4 and 2.6 tonnes per hectare, close to the national mean of 2.5 tonnes per hectare. Although the country's main sunflower belt lies in the southern regions, the northeast also recorded good results that year. In fact, 2021 marked a record season for Romania, with national production reaching nearly 2.82 million tonnes harvested from about 1.1 million hectares, translating into an average yield of approximately 2.53 tonnes per hectare. As the leading producer of sunflower within the European Union, Romania benefited that year from both favorable weather and the performance of its adapted hybrids. Crops in many areas flowered and filled seeds before late summer dryness set in, ensuring good productivity.

Within the northeast, soils with strong fertility, particularly those rich in phosphorus and micronutrients such as boron, produced the best yields. Fields with a history of manure application or residual fertilizers from preceding wheat crops also showed vigorous sunflower development, underlining the importance of nutrient availability. The crop's deep rooting system, which can extend beyond one meter, allows sunflower plants to exploit moisture and nutrients from a large soil volume. This makes them less immediately dependent on topsoil conditions than maize. Nonetheless, the quality of the topsoil still plays an important role, as good tilth and structure are essential for early root establishment and successful stand development.

Table 4 Sunflower yield performance in NE Romania and nationally (2021)

Location or scale	Yield (t/ha)	Observations
NE Romania (regional average)	2.4–2.6	Yields aligned with national levels; good weather during flowering and seed filling
Romania (national average)	~2.53	Highest national sunflower output on record (~2.818 million tonnes from ~1.1 million ha)
Fertile soils (high P, boron; manure/fertilizer history)	>2.6	Enhanced yields where nutrient supply was strong and soil fertility had been maintained
Deep Chernozem subsoils	Stable >2.5	Deep rooting allowed access to moisture and nutrients, buffering against late-season

		dryness
Thinner soils with poorer nutrient reserves	<2.4	Lower yields where subsoil was restrictive or fertility management was weaker

The 2021 sunflower harvest highlighted the crop's strong adaptability even under moderate climatic stress, with yields in northeastern Romania closely matching national averages. Differences between fields were largely shaped by soil fertility, especially the availability of phosphorus and micronutrients, as well as by the depth and condition of the subsoil. While favorable weather created the conditions for Romania to achieve record production that year, the results make it clear that long-term yield stability depends on sound management practices. Regular manuring, careful retention of crop residues, and efforts to preserve subsoil structure all proved to be critical factors in sustaining high levels of sunflower productivity.

A comparison with Ukraine's sunflower yields provides further perspective. As one of the world's leading producers, Ukraine also enjoyed a record season in 2021, with average yields of about 2.46 tonnes per hectare. The following year brought both war-related disruptions and drought, yet the national average still reached around 2.14 tonnes per hectare, representing a decline of roughly 13 percent. This reduction was comparable in scale to the drop observed in maize and is noteworthy for remaining relatively high under such challenging circumstances. The figures suggest that farmers in Ukraine, particularly in the central and northern regions that were actually harvested, managed to sustain reasonable yields through the use of adapted hybrids and perhaps a more favorable distribution of rainfall. Interestingly, Ukraine's 2022 average yield of approximately 2.14 tonnes per hectare still exceeded Romania's 1.93 tonnes per hectare. Part of this difference may be attributed to the naturally higher fertility of Ukrainian chernozem soils, which can continue to support good sunflower performance as long as a minimum level of moisture is available. Another likely factor is that planting in some of the driest southern zones was reduced, meaning that the harvested crop came predominantly from better-watered regions, thereby raising the national average.

By 2023, yields in both countries showed clear signs of recovery. Romania's national average rose to about 2.16 tonnes per hectare, an increase of roughly 12 percent compared with 2022, while Ukraine's yields were projected at around 2.4 to 2.42 tonnes per hectare, marking a 13 percent improvement. This rebound is evident in yield trend data, with both lines rising in 2023 and Ukraine maintaining a slight advantage over Romania. These outcomes illustrate that once rainfall patterns normalized, soils were capable of supporting strong sunflower production. At the same time, the results point to a persistent yield gap: under similar climatic conditions in 2023, Ukraine's yields remained somewhat higher, suggesting that soil fertility or management practices may explain part of the difference. It is also worth noting that Romania's 2023 sunflower yield, although improved, was reported to be around 11 percent lower than its recent five-year average. This may reflect lingering effects of the 2022 drought and soil stress, or alternatively, it may be that the five-year benchmark was elevated by exceptionally productive seasons such as 2017 and 2021.

Table 5 Comparative sunflower yield trends in Romania and Ukraine (2021–2023)

Indicator	Romania	Ukraine
2021 Yield (t/ha)	~2.53 (national average; NE ~2.4–2.6)	2.46 (record high)
2022 Yield (t/ha)	1.93	2.14
% Change (2021–2022)	–24%	–13%
2023 Yield (t/ha)	~2.16	2.40–2.42
% Change (2022–2023)	12%	13%
Key factors	Severe 2022 drought; soil exhaustion; lingering effect below 5-year average	Fertile chernozem soils; patchy drought impact; war reduced harvest area in driest south, skewing yields upward

The comparative figures show that Romania experienced a much steeper drop in sunflower yields in 2022, about 24 percent, compared with a 13 percent decline in Ukraine. This difference reflects underlying contrasts in soil fertility, crop management practices, and the overall resilience of farming systems. By 2023, yields in both countries recovered, yet Romania's average of 2.16 tonnes per hectare still fell slightly short of its recent five-year mean, while Ukraine's output of around 2.4 tonnes per hectare came close to pre-crisis levels. These patterns highlight the protective role of fertile chernozem soils, the adoption of improved hybrids, and the efficiency of larger, more consolidated farm structures in cushioning the effects of climatic and external shocks. In contrast, Romania's more fragmented agricultural landscape and lower reserves of soil organic matter make its production systems more vulnerable when drought conditions arise.

An important observation regarding sunflower production relates to the effect of soil compaction on root development. During the dry season of 2022, fields with a plough pan or compacted layer showed plants developing shallower roots and displaying signs of stress much earlier, with leaf scorching evident around the flowering stage. Although sunflower typically develops a robust taproot capable of penetrating dense soil, its ability to do so is limited when the soil is both highly compacted and dry. Penetrometer measurements taken in several fields indicated resistance values above 3 MPa at a depth of about 25 centimeters, essentially creating a barrier to deeper rooting. In these conditions, yields were on average 10 to 15 percent lower than in fields where compaction had been reduced through deep ripping or biological drilling with cover crops (Bota et al., 2006). This highlights the role of soil structure as a fundamental component of soil quality for sunflower, not only for maize. Supporting evidence from research in western Romania has shown that deep loosening treatments can significantly increase sunflower yields for at least two years after application. While our study did not conduct a formal trial of subsoiling, field observations in 2023 suggested that the most productive sunflower crops were often grown on land that had been ripped or chiseled in recent seasons, allowing roots to penetrate more deeply and make better use of available moisture and nutrients.

Comparison between Romania and Ukraine regarding yields and rationale

When comparing agricultural performance in northeastern Romania with that of similar regions in Ukraine, several clear differences become apparent, most of them linked to soil quality, levels of organic matter, and prevailing farming practices. In the case of maize, Ukraine has consistently achieved higher yields, often in the range of 7 to 8 tonnes per hectare, whereas Romania has typically produced around 5 tonnes per hectare, even in favorable years such as 2021. Sunflower yields are somewhat closer between the two countries, and in certain seasons Romania has even outperformed its neighbor, yet Ukraine generally retains a more stable advantage. The main explanation lies in the superior fertility and greater depth of Ukrainian chernozem soils, which contain higher organic matter—often between 3 and 4 percent compared with 2 to 3 percent in Romania. This organic richness allows Ukrainian soils to store water more effectively, withstand drought stress, and supply nutrients more consistently. By contrast, many soils in northeastern Romania have been gradually thinned by erosion, with substantial losses of humus over the past decades. As a result, their ability to buffer crops against climatic extremes has diminished, leaving yields more exposed to variability.

Soil erosion and land degradation are more severe in Romania, largely because of the region's hilly terrain, which contributes to the loss of an estimated 150 million tonnes of soil each year. By contrast, Ukraine's broad and relatively flat steppes have allowed extensive areas of land to remain largely unaffected by erosion. The difference in resilience became especially clear during the drought of 2022. Ukrainian soils retained more moisture and benefited from timely rainfall, and in many cases the adoption of no-till practices helped reduce yield losses. Romanian farms, on the other hand, remained heavily dependent on plowing, and yields dropped sharply, particularly in counties such as Iași. Structural differences in farming also play a role. Ukraine's large, consolidated farms generally have better access to investment capital, modern technologies, and precision agriculture tools, while Romania's fragmented smallholder farms often lack the means to implement such innovations. Crop rotation practices further accentuate the contrast. Ukrainian farms make more frequent use of legumes and conservation-based rotations, which help sustain soil fertility and maintain structure. In northeastern Romania, however, small farms often rely on repeated maize or simple maize–sunflower rotations, a pattern that accelerates soil exhaustion and increases vulnerability to pests and diseases.

A key finding is the clear difference in yield stability between the two countries. Ukraine has shown more consistent results from one year to the next, while Romania's production is far more variable. This is most visible in maize, where yields can collapse by as much as 40 percent during a drought and then recover sharply the following season. Such volatility reveals a higher degree of vulnerability, linked both to weaker soils and to less flexible farming practices. The comparison suggests that Romania's best strategy for closing the productivity gap lies in strengthening soil health. Efforts such as rebuilding organic matter, reducing erosion, and promoting practices like cover cropping, reduced tillage, and longer crop rotations would play a crucial role. These measures may not always push yields higher in favorable years, but they serve as a safeguard against severe losses during droughts, ultimately ensuring greater stability and long-term sustainability in crop production.

Table 6 Key differences in agricultural performance between NE Romania and Ukraine

Aspect	NE Romania	Ukraine
Maize yields	Typically ~5 t/ha (even in favorable years like 2021)	Consistently 7–8 t/ha
Sunflower yields	~2.5 t/ha; occasionally higher than Ukraine in good years, but variable	~2.4–2.6 t/ha; more stable across years
Soil organic matter (SOC)	2–3% on average; losses of humus over decades	3–4% in productive zones; richer "chernozem" profile
Soil depth & erosion	Hilly terrain; ~150 million tonnes soil lost annually; thinner topsoil	Flat steppes; large areas with minimal erosion
Resilience to drought (2022 example)	Sharp yield drops (maize down ~40% in some counties, e.g., Iași); reliance on plowing exacerbated water loss	Smaller yield declines; higher SOC improved water retention; timely rains; widespread no-till practices
Farm structure	Fragmented smallholder farms; limited capital; slow adoption of modern technology	Large consolidated farms; better access to investment, machinery, precision farming
Crop rotation practices	Often maize–sunflower cycles or continuous maize; weak diversification; accelerated soil exhaustion	Wider rotations including legumes and conservation crops; improved soil fertility and structure
Yield stability	High volatility; production swings widely with climate (–40% in drought, sharp recovery after)	More consistent yields; soils and practices buffer climate stress

Source: authors elaboration

The comparative analysis shows that Ukraine's stronger and more consistent crop yields are largely sustained by its fertile chernozem soils, rich in humus, combined with lower erosion rates and the use of more advanced farming systems. In contrast, the northeastern regions of Romania struggle with soil degradation, reduced levels of organic matter, and highly fragmented farm structures, factors that contribute to sharp fluctuations in yields during years of climatic stress. Closing this gap will require a sustained focus on restoring soil health in Romania. Key measures include controlling erosion, rebuilding organic matter, diversifying crop rotations, expanding the use of cover crops, and reducing tillage intensity. While such practices may not necessarily raise yields dramatically in favorable years, they act as a critical buffer against drought and provide the foundation for stable and sustainable productivity over the long term.

CONCLUSIONS

This research set out to examine how changes in soil quality influence the yield performance of maize and sunflower, with a particular focus on northeastern Romania and a comparative perspective from Ukraine. The findings make it clear that soil quality plays a central role in both productivity and yield stability. Over the past three years, which included seasons of favorable weather as well as severe drought, fields with healthier soils—those richer in organic matter, with stronger structure and adequate nutrient reserves—consistently produced higher yields and maintained performance more effectively than soils that had become degraded.

Soils with higher organic matter content offered clear advantages for crop performance. Improved water retention and nutrient availability translated into stronger yields for both maize and sunflower under normal conditions, while also helping to cushion the impact of drought. For example, fields with around 3 percent soil organic carbon typically produced between half a tonne and one tonne more maize per hectare compared with fields that contained closer to 2 percent, assuming other conditions were similar. During the 2022 drought, plots with higher organic matter maintained healthier plant growth and ultimately yielded significantly more than soils that had been depleted of carbon, even though overall production was reduced by the extreme weather.

The drought of 2022 led to severe declines in yield, with maize dropping by as much as 40 to 50 percent and sunflower by roughly 25 percent in northeastern Romania. Yet differences between farms showed that those with stronger soil management practices were less affected. Both field data and farmer observations confirmed that measures such as conservation tillage, retaining crop residues, and applying organic amendments helped mitigate the losses. By 2023, farms that had invested in building soil health saw their yields recover more quickly, underscoring the idea that soil resilience is not just an agronomic asset but a vital part of adapting agriculture to a changing climate.

The comparative assessment showed that Romania's yields, especially for maize, continue to lag behind those of Ukraine even under similar climatic conditions. A key factor lies in differences in soil quality and management intensity. Ukraine's fertile chernozem soils, combined with large-scale modern farming systems, support consistently higher yields, with maize harvests of 7 to 8 tonnes per hectare being common compared with 5 to 6 tonnes per hectare in Romania. Furthermore, Ukraine's crops proved more resilient to drought in 2022, highlighting that addressing Romania's soil challenges—such as erosion and low organic matter—could help narrow this productivity gap. Using Ukraine as a benchmark emphasizes that Romania holds similar potential if its soil resources are managed more effectively.

The study also makes clear that farming practices have a direct impact on soil health and, by extension, crop performance. In northeastern Romania, decades of repeated ploughing and limited organic matter inputs have contributed to soil compaction and nutrient depletion, pointing to the need for alternative cultivation methods. Evidence from both experiments and field practice indicates that approaches such as deep loosening, no-till or strip-till systems, the use of cover crops, and balanced fertilization can improve soil properties and boost yields. In some cases, combining organic amendments like manure or straw with mineral fertilizers nearly doubled production while significantly increasing soil carbon levels. These findings suggest that targeted interventions aimed at strengthening soil quality not only enhance immediate crop output but also build the foundation for long-term fertility and resilience.

Soil erosion has emerged as a quiet but powerful factor limiting crop productivity in the region. Fields affected by erosion often have thinner topsoil, weaker structure, and reduced capacity to hold moisture, all of which translate into lower yields and greater vulnerability during drought years. Since much of northeastern Romania's farmland lies on sloping terrain, the introduction of erosion control practices such as terracing, contour farming, or the establishment of grass strips is critical. These measures help conserve the upper soil layers that contain humus and nutrients—the foundation of soil fertility and crop growth. Our analysis suggests that preventing and reversing erosion will be central to sustaining future yields. Without such efforts, any short-term progress achieved through fertilization or the adoption of new hybrids risks being offset by the steady depletion of the soil itself.

Beyond raising average yields, improving soil quality is about ensuring stability across years. The study demonstrated that yields fluctuate widely with weather conditions, but soils in better health act as a buffer, softening the impact of droughts and extremes. For farmers, this stability is critical to secure household income, while at the regional level it underpins food security. As climate variability intensifies, the ability of soils in northeastern Romania to withstand stress will determine the resilience of the entire agricultural system. One of the key conclusions of this research is therefore the recognition of soil quality enhancement as a strategic investment in resilience. Practical measures should include policies and farm support programs that incentivize the build-up of soil organic carbon. Beyond agronomic benefits, this approach aligns with broader climate goals, since increasing soil carbon not only sustains productivity but also contributes to climate change mitigation.

This study confirms that safeguarding and improving soil quality is fundamental to securing both high and stable yields of maize and sunflower. The data from the drought year provide strong evidence that soil degradation directly translates into yield losses, while measures that strengthen soil health bring tangible improvements in productivity. From a scientific standpoint, these results add to the broader understanding of how soil, plants, and climate interact. From a practical perspective, they offer clear guidance for developing better agronomic strategies. The originality of this research lies in its integrative perspective: by combining farm-level data, climatic variability, and a cross-country comparison, it presents a holistic view that emphasizes a simple yet often overlooked truth—crop productivity begins and ends with the condition of the soil.

Looking ahead, northeastern Romania has the opportunity to apply these lessons by increasing organic matter inputs, reducing erosion, and adapting successful practices seen in neighboring Ukraine. With careful management and patience, soils can regenerate and continue to serve as the foundation of agricultural prosperity in the region. The dynamics of soil quality, once regarded as slow or marginal, must now be recognized as central and highly influential. By acting on this knowledge, stakeholders—from individual farmers to national policymakers—can help ensure that the agricultural legacy of this region is not only maintained but also strengthened for future generations.

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