

Evolution of Soil Chemical Characteristics under the Impact of Various Agricultural Technologies and Economic Scenarios in Southern Romania

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ABSTRACT

Two soil tillage systems - conventional system (classical) and the conservative system (minimal tillage/no-tillage) - were evaluated at three locations in southern Romania: Mavrodin, Teleorman County; Sohatu, Călărași County and Afumați, Dolj County. The soils identified in the studied areas are Chernisoles, with the types cambic Chernozem and typical Faeozom and Luvisoles with the type reddish Preluvosol (WRB-SR 2014). Soil samples were collected at depths of 5-10; 25-30 and 45-50 cm depths and their chemical properties were determined in the laboratory according to standardized methodology.

At Afumați, the minimum tillage system showed clear advantages over the conventional one, by maintaining an optimal pH (weakly acid-neutral), a more stable humus content and a more balanced distribution of nutrients (nitrogen, phosphorus and potassium). In contrast, conventional tillage favors the alkalization of the soil, the loss of organic matter in depth and a reduced mobility of nutrients. Conservative technology contributes to the preservation of soil fertility and ensures long-term sustainable agriculture. Comparing the two systems of soil tillage in the Mavrodin area, the minimum tillage technology is distinguished by a more stable pH, a better accumulation of organic matter on the surface, as well as an increased concentration of nitrogen and potassium in the upper layers, favorable aspects for soil fertility. In contrast, conventional tillage leads to deep soil acidification, a more uniform but weaker distribution of humus and nutrients, and potential leaching losses. Overall, the conservative system better supports long-term soil health and balance. The no-till (conservative) technology applied at Sohatu, favors a gradual improvement of the soil reaction (pH), especially in the deep layers, as well as a better accumulation of organic matter at the surface. Although the total nitrogen content is lower than the conventional system, its distribution is more stable over depths. Mobile phosphorus is more concentrated in the superficial layer, and mobile potassium shows high values in 2024, with a slight decrease in 2025. The conventional system maintains higher values of nitrogen and phosphorus in 2024, however, these declined markedly in 2025, indicating a potential long-term nutrient imbalance. Overall, the conservative system provides a better nutrient balance and improved soil sustainability.

Keywords: agricultural technologies, minimum tillage, no-tillage, conventional tillage, chemical properties.

INTRODUCTION

With projections indicating that the global population may reach 9 billion by 2050, food security concerns are intensifying, necessitating soil health preservation and degradation mitigation (Oliver and Gregory, 2015). According to the United Nations, an annual loss of 24 billion

tons of fertile soil is occurring, a trend that could lead to over 90% of the Earth's surface area being degraded by 2050 (Gomiero, 2016). Panagos et al. (2024) utilized microeconomic models to determine that 12 million hectares of agricultural land in the European Union had experienced soil degradation. This resulted in economic losses in the agricultural sector amounting to

approximately EUR 300 million and imposed a strain on natural resources (Țopa et al., 2025). To alleviate the detrimental impacts of agricultural systems and guarantee their enduring sustainability, it is imperative to use management measures that improve or maintain the soil quality (Doran and Zeiss, 2000).

In the face of climate change, water conservation is essential for agriculture sustainability and food security. Crop production in Argentina is mainly rain-fed, therefore the yield is highly dependent on soil water storage. Soil water content and availability affects oxygen diffusion, temperature and tolerance to compacted soils (Martino, 2003; Hossne-García et al., 2012).

Tillage practices considerably impact soil health by changing fundamental physical, chemical, and biological components influencing soil function and the crop yield (Omer et al., 2024). Because the farming conventional systems have caused soil degradation in many countries, the technologies concerning the mechanization of agricultural practices must be adapted to the requirements concerning soil and water protection, and soil conservation practices are necessary in the areas with more sensitive soils to degradation (Săndoiu, 1996; Guş, 1998; Sin, 2000; Lal, 2006).

The adoption of good agricultural practices, e.g. improving rotation with forage crops, returning crop residues to soil, minimum tillage, growing of green manure crops and supplying soil with organic matter (compost, manure, etc.), determines the increase in the content of organic matter from soil and maintains the ecological and socio-economic functions of soil and yield sustainability (Jitäreanu et al., 2009a). It has been widely established that soils under long-term NT or reduced tillage systems generally contain higher amounts of SOC in the soil surface than under CT (Bajracharya et al., 1998; West and Marland, 2002; Freibauer et al., 2004; Conant et al., 2017; Thomas et al., 2007).

Change in frequency and intensity of tillage practices alters soil properties, distribution of nutrients, and soil organic matter in the soil profile. These changes

become stable with time and could affect availability of nutrients for plant growth, crop production, and soil productivity. Long-term NT systems accumulate nutrients in the soil surface, whereas MP (moldboard plow) distributes nutrients relatively uniformly through the tillage depth. Stratification of nutrients has been observed in two long-term tillage studies under NT, whereas soil mixing promotes uniform distribution of nutrients in MP and CP (chisel plow) (Mackay et al., 1987; Karlen et al., 1991; Ismail et al., 1994). In contrast, Karlen et al. (1994) and Franzluebbers and Hons (1996) observed differences in nutrients distributions due to tillage system. Soil pH decreases at the soil surface in NT (no-till) because of surface-applied N (Blevins et al., 1983), soil acidity (Dick, 1983), and more organic matter (Karlen et al., 1991, Ismail et al., 1994; Kitur et al., 1994; Franzluebbers and Hons, 1996), and found a higher soil pH in the surface soil of NT than MP that resulted from slow mixing of surface-applied lime. Organic matter plays an important role in nutrient availability and soil aggregate stability. Soil productivity decreases when soil organic matter (SOM) declines (Bauer and Black, 1994) High residue-producing crops in combination with NT increase SOM (Havlin et al., 1990).

Conservation and no-tillage practices have been incorporated as strategies to improve agricultural soils conservation (Fabrizzi, 2005). No-tillage systems, particularly direct seeding, were introduced in the 1990s and adopted at an exponential rate (Duval et al., 2013). Argentina has applied no-tillage on a large scale (Soracco et al., 2010) reaching to, approximately, 90% of total cropping land (Nocelli, 2017). No-tillage systems made it possible to perform agriculture in less productive areas (Derpsch et al., 2010). Soil properties sensitive to management practices, could be used as indicators and contribute to the diagnosis of a particular production system. Therefore, they could support further decision making regarding which techniques should be implemented to develop a productive system based on a sustainable, resource conservative, energy-efficient and

socially viable agriculture (Duval et al., 2013). A minimum number of soil properties should be selected and quantified to assess soil quality (Govaerts et al., 2006).

Finally, monitoring changes in soil quality indicators associated with a particular environment could determine if a tillage system is in a situation of stability, improvement or degradation (Shukla et al., 2006).

MATERIAL AND METHODS

Study area

This research was carried out in three distinct regions of Romania affected by the aridification process, selected based on their pedoclimatic characteristics and agricultural relevance. The three locations are: Afumați, Dolj County (Latitude: N 44°00.637'; Longitude: E 023°42.667'), where the representative soil type is a Cambic Chernozem, according to the WRB-SR 2014 classification system; Mavrodin, Teleorman County (Latitude: N 44°05.859'; Longitude: E 025°26.918'), characterized by the presence of a Reddish Luvisol and Sohatu, Călărași County (Latitude: N 44°35.756'; Longitude: E 02°65.7964'), where the dominant soil type is a Typical Phaeozem, as defined by WRB-SR 2014.

Description of climatic factors in each study area

The climate of the three analyzed regions falls within the transitional zone between moderate continental and excessive continental climate, characterized by hot, dry summers and relatively cold winters, with a low and uneven annual rainfall regime, typical of southern and southeastern Romania. The main climatic factors for each location are as follows: climate type Afumați, Dolj County: continental with sub-mediterranean influences. Average annual temperature: approx. 11.5-12°C. Average annual precipitation: 450-550 mm, with a decreasing trend in recent decades.

The annual precipitation generally ranges between 500 and 600 mm, based on multiannual averages calculated for the

reference period 1991-2020 [National Meteorological Administration (ANM), 2020].

Mavrodin, Teleorman County, climate type: continental, characteristic of the plains. Average annual temperature: approx. 11.2°C. Average annual precipitation: 450-500 mm, unevenly distributed (Romanescu and Stoleriu, 2017). Dominant natural vegetation includes steppe grasslands, with drought-resistant herbaceous species such as: *Stipa spp.*, *Festuca valesiaca*, *Agropyron cristatum* *Koeleria spp.*, *Poa spp.* Sparse shrub species can still be found in marginal or less disturbed areas, including *Caragana*, *Prunus spinosa*, and *Crataegus monogyna*. The annual precipitation in the Mavrodin area (Teleorman County) typically ranges between 500 and 550 mm.

Sohatu, Călărași County, climate type: excessive continental. Average annual temperature: 11-11.4°C. Average annual precipitation: 400-500 mm, often insufficient for crop requirements (WorldClim - Global Climate Data, 2020). Characteristic Native Species: *Festuca valesiaca*; *Stipa capillata*; *Agropyron cristatum*. These species are xerophytic and represent typical steppe grasses adapted to dry soils and pronounced seasonal temperature variations. Herbaceous species: *Artemisia campestris*; *Thymus serpyllum*; *Achillea millefolium* (Pușcaș and Silaghi, 2020). At the transition between steppe and former forested areas, a number of shrubs and small trees were historically present, particularly in areas with slightly better moisture availability: *Crataegus monogyna*, *Cornus sanguinea*, *Prunus spinosa*. These species represent natural ecotonal vegetation in the forest-steppe mosaic, often serving as indicators of semi-natural remnants in an otherwise anthropized landscape. Former Arboreal Vegetation: *Quercus pedunculiflora*; *Quercus robur* (INCDPAPM-ICPA Bucharest, 2019). The average annual precipitation in the Sohatu area is estimated to range between 450 and 550 mm, based on long-term climatological records (30-year multiannual averages). This value places the region within the semi-arid to sub-humid climatic classification, which

frequently leads to hydric stress, particularly during the warm season. Such climatic conditions are limiting factors for both natural vegetation and agricultural productivity, especially in the absence of irrigation infrastructure [National Meteorological Administration (ANM), 2020].

Soil samples

Agro physical profiles were dug in the soil and samples were taken by 5-10; 25-30; and 45-50 cm depths. The analyses and determinations were performed according to current methodology and standards (Florea and Munteanu, 1987, 2003).

Laboratory analyses

Laboratory analyses were conducted to determine soil pH, organic matter content, and nutrient availability.

Determination of soil pH: measured in aqueous suspension (1:2.5 ratio); according to SR 7184-13:2001; Determination of humus content: wet oxidation method; according to STAS 7184/21-82; Determination of total nitrogen (Nt): Kjeldahl method; according to STAS 7184/2-85; Determination of available phosphorus (P_{AL}): ammonium acetate-lactate extraction; according to STAS 7184/19-82;

Determination of available potassium (K_{AL}): ammonium acetate-lactate extraction; according to STAS 7184/18-80.

Assessment of the impact of different soil tillage systems in the Afumați Area (Dolj County)

In the field managed under minimum tillage, soil pH values fall within the slightly acidic to neutral range (6.4-7.0), which promotes an optimal and balanced availability of essential nutrients for plant growth. In contrast, under conventional tillage (classic system), pH values are significantly higher, reaching 7.7-8.2 in the year 2024, indicating a tendency toward soil alkalization, particularly evident in the deepest layer (45-50 cm) (Table 1).

Under the conservation tillage system, the humus content remains relatively stable throughout the soil profile, corresponding to a moderate supply level, with slightly higher

values in the surface layer (2.92-2.96%). This vertical distribution reflects an efficient preservation of organic matter and a lower degree of mechanical soil disturbance, which favors humus accumulation in the upper horizons.

Total Nitrogen Content (Nt%). In the minimum tillage system, the total nitrogen content remains at a relatively low level, with no significant variations across the analyzed soil depths. However, the highest value was recorded at the 25-30 cm depth, reaching 0.141% in 2024, which may indicate a temporary accumulation of nitrogen in the middle layer of the soil profile, possibly influenced by the distribution of plant residues and microbial mineralization processes.

In contrast, under the conventional (classic) tillage system, the highest concentration of total nitrogen was observed in the surface layer, specifically at a depth of 5-10 cm, suggesting a more intense mobilization of nitrogen in the upper horizons, likely as a result of mechanical incorporation and fragmentation of organic residues through repeated soil disturbance.

In the minimum tillage field, phosphorus availability was classified as moderate in spring 2024. Phosphorus values ranged from 11 mg/kg at a depth of 45-50 cm (considered low) to a high of 40 mg/kg at 25-30 cm. In 2025, phosphorus values were slightly lower compared to the previous year. However, phosphorus content remained within the moderate range in the surface layer (e.g., 28 mg/kg at 0-5 cm), while a decreasing trend with depth was observed, likely due to plant uptake. In the conventional tillage field (2024), available phosphorus content was high in the surface layer at both sampling times, followed by a gradual decline with increasing depth. Phosphorus availability was found to be higher and more accessible to plants under the minimum tillage system, which is likely attributed to the slightly acidic soil pH, enhancing phosphorus solubility and mobility.

Under the minimum tillage system, available potassium content was classified as low across all three soil depths, based on both

sets of laboratory analyses. In the conventional tillage field, during the spring 2024 sampling, available potassium levels were moderate in the surface layer (5-10 cm), with a value of 143 mg/kg, but showed a

sharp decrease with increasing depth, reaching only 50 mg/kg in the deepest layer. This distribution indicates a higher accumulation near the surface and limited vertical mobility of potassium within the soil profile.

Table 1. Impact of soil tillage systems on Afumați, Dolj County

Afumați	Sampling depth	Tillage system			
		Minimum tillage		Conventional tillage	
		spring 2024	spring 2025	spring 2024	spring 2025
pH	5-10	6.58	6.64	7.98	6.39
	25-30	6.41	6.65	8.05	6.96
	45-50	7.00	7.74	8.24	7.60
Humus%	5-10	2.92	2.96	2.92	2.90
	25-30	2.56	2.90	2.32	2.55
	45-50	2.32	2.31	1.67	2.43
Nt%	5-10	0.131	0.128	0.154	0.126
	25-30	0.141	0.132	0.118	0.106
	45-50	0.117	0.093	0.116	0.112
P _{AL} mg/kg	5-10	30	28	52	49
	25-30	40	15	21	22
	45-50	11	12	12	15
K _{AL} mg/kg	5-10	107	94	143	167
	25-30	119	89	66	95
	45-50	74	80	50	83

Assessment of the impact of different soil tillage systems in the Mavrodin Area (Teleorman County)

In the experimental field where the conservation tillage system with minimum tillage was applied, the soil pH showed an improving trend in the deepest layer (45-50 cm), where the value increased significantly in 2025 (reaching 6.71). In contrast, in the surface layer, the soil reaction exhibited slight acidification, which can be attributed to the accumulation of organic matter at the surface and to intensified microbiological activity.

In the field under conventional tillage, the pH decreased notably at 25-30 cm depth, from 6.37 in 2024 to 5.59 in 2025, indicating pronounced acidification caused by intensive soil disturbance, which exposes the soil to leaching and mineralization processes (Table 2).

When comparing the two agricultural systems applied in the Afumați area, it is evident that minimum tillage helps maintain a more stable soil reaction and even improves pH values in deeper soil layers. On the other hand, the conventional system shows a trend

toward acidification at the intermediate depth, which may negatively affect nutrient availability and long-term soil health.

Under the minimum tillage system, in the surface layer (0-5 cm), humus content recorded high values: 3.52% in 2024 and 3.79% in 2025, indicating a clear accumulation of organic matter, with values decreasing progressively with depth (Table 2). In contrast, under the conventional tillage system, humus content in the surface layer (5-10 cm) was lower than in the minimum tillage system, with values of 3.04% in 2024 and 3.20% in 2025. However, in the deepest layer (45-50 cm), humus values were higher than those recorded under minimum tillage (2.62% in 2024 and 1.66% in 2025), indicating a more uniform distribution of organic matter throughout the soil profile.

Overall, the minimum tillage system promotes the accumulation of organic matter in the surface horizon, while the conventional tillage system results in a more even distribution across all sampling depths, but with lower concentrations at the surface.

Under the conservation tillage system, total nitrogen content falls within the moderate supply class in the surface layer, indicating a tendency for nitrogen accumulation in the upper soil horizons. This pattern is likely due to reduced mechanical disturbance and the preservation of organic matter.

In contrast, the conventional tillage system maintains a moderate to low level of total nitrogen supply across both sampling sets, which may be associated with increased nitrogen losses through mineralization and leaching, as well as a decrease in organic matter content.

The minimum tillage field maintains a moderate level of available phosphorus in the surface layer, but a significant decline is observed over time, indicating plant uptake

and limited downward mobility of phosphorus within the soil profile.

In contrast, the conventional tillage field shows a generally lower overall phosphorus content, but with a more uniform distribution across the profile, and a slight increase in surface concentration observed in spring 2025.

Under the minimum tillage system, available potassium is concentrated in the surface layer, with high values. In contrast, in the conventional tillage system, potassium is more evenly distributed throughout the soil profile, showing moderate to low values, but with lower concentrations in the topsoil.

In spring 2025, an increase in potassium content at greater depths was observed, which may indicate leaching losses and a reduction in potassium availability for shallow root systems.

Table 2. Impact of soil tillage systems on Mavrodin, Teleorman County

Mavrodin	Sampling depth	Tillage system			
		Minimum tillage		Conventional tillage	
		spring 2024	spring 2025	spring 2024	spring 2025
pH	5-10	6.06	5.94	5.89	5.82
	25-30	5.80	6.01	6.37	5.59
	45-50	6.23	6.71	6.12	6.18
Humus%	5-10	3.52	3.79	3.04	3.20
	25-30	2.74	3.43	2.74	2.37
	45-50	2.00	1.54	2.62	1.66
Nt%	5-10	0.177	0.176	0.150	0.134
	25-30	0.140	0.130	0.136	0.108
	45-50	0.110	0.061	0.157	0.085
P _{AL} mg/kg	5-10	49	35	15	25
	25-30	32	18	14	13
	45-50	8	8	15	12
K _{AL} mg/kg	5-10	215	212	127	77
	25-30	91	91	137	113
	45-50	111	164	113	169

Assessment of the impact of different soil tillage systems in the Sohatu, Călărași County

In the conservation tillage field (no-till), the soil reaction was slightly acidic in the first two sampling depths but increased significantly in the deeper layer, indicating a slight alkalization with depth (2024). A general increase in pH values was observed compared to the previous year, particularly in the middle and lower soil layers, suggesting an improvement in soil reaction in 2025.

In the conventional tillage field, soil pH values were slightly higher than those recorded under the conservation system, with a similar increasing trend with depth (2024). At depths of 5-10 cm and 45-50 cm, the soil reaction approached neutral values (Table 3).

The conservation system with no-till practices maintains a moderate level of organic matter, especially at the 5-10 cm depth, across both sampling periods. Both experimental variants exhibit a clear pattern of decreasing humus content with increasing soil depth.

It can be stated that the no-till system contributes slightly more organic matter, primarily due to the presence of plant residues on the soil surface, which enhance organic matter input and reduce mineralization rates.

In the conventional tillage system, there is a tendency to maintain a higher level of total nitrogen supply compared to the conservation system. In the conservation system, total nitrogen values vary between the two sampling periods, with a slight increase in the surface layer (5-10 cm) in 2025, which may be attributed to the accumulation of organic matter at the surface and enhanced biological activity. At the other two sampling depths, a decreasing trend in nitrogen content was observed with increasing depth, indicating reduced vertical mobility and a limited input of organic material in the lower layers of the soil profile.

Under the no-tillage system, the available phosphorus content falls within the moderate to low supply class, with higher values concentrated in the surface layer of the soil. This distribution indicates limited vertical mobility of phosphorus and reflects the direct contribution of surface plant residues, as well

as the influence of soil pH on phosphorus availability.

In the conventional tillage system, higher values of available phosphorus were recorded in spring 2024, followed by a sharp decline in 2025, suggesting intensive uptake by plants and possible losses through fixation or leaching processes, commonly associated with repeated mechanical soil disturbance.

In the no-tillage field, the available potassium content fell within the high to moderate supply class in spring 2024, but experienced a significant decrease in 2025. This decline may be explained by increased plant uptake, combined with the absence of residue incorporation and the limited mobility of potassium within the soil profile, which is typical for reduced tillage systems.

In the conventional tillage field, available potassium remained at a well-supplied level in spring 2024, but declined sharply in 2025 across all three sampling depths. This trend may be attributed to both intensified plant uptake and losses through leaching or fixation into less available forms, processes that are amplified by repeated mechanical disturbances affecting the chemical balance of the soil.

Table 3. Impact of soil tillage systems on Sohatu, Călărași County

Sohatu	Sampling depth	Tillage system			
		Minimum tillage		Conventional tillage	
		spring 2024	spring 2025	spring 2024	spring 2025
pH	5-10	6.07	6.21	6.23	6.85
	25-30	5.99	6.39	6.21	6.11
	45-50	6.52	6.72	6.71	6.82
Humus%	5-10	3.40	3.02	2.98	2.90
	25-30	2.74	2.60	2.68	2.48
	45-50	2.32	2.11	2.21	2.17
Nt%	5-10	0.103	0.137	0.145	0.137
	25-30	0.133	0.125	0.144	0.121
	45-50	0.114	0.097	0.110	0.109
P _{AL} mg/kg	5-10	21	16	16	11
	25-30	18	13	22	8
	45-50	11	11	14	7
K _{AL} mg/kg	5-10	239	137	253	177
	25-30	189	137	208	106
	45-50	195	117	206	130

Comparative economic analysis: minimum tillage vs. conventional tillage in southern Romania

A major economic advantage of minimum tillage systems compared to conventional tillage (plowing + harrowing) is the substantial reduction in fuel consumption per hectare. Experimental data from Cluj County, on mollic soils highlight consistent differences for the main crops cultivated in southern Romania, including *Triticum*

aestivum L., *Zea mays* L. and *Glycine max* (L.) Merr. (Moraru et al., 2015; Gîngu et al., 1999).

Under conventional plowing, fuel consumption averages 61.6 L/ha for wheat, 95.6 L/ha for maize and 67.6 L/ha for soybeans. By contrast, minimum tillage using a chisel reduces consumption to 51.3-71.7 L/ha, while rotary harrowing further lowers it to 39.5-50.4 L/ha, depending on the crop (Figure 1) (after Moraru et al., 2015).

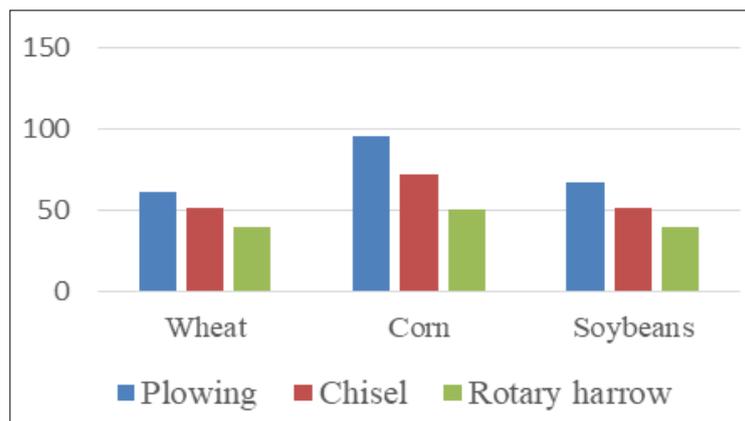


Figure 1. Fuel consumption under different tillage systems (L/ha)

Overall, minimum tillage systems require only 65-85% of the fuel consumed under conventional plowing (Neacșu et al., 1997). At an average diesel price of approximately 6.2 RON/L, annual fuel savings are estimated at around 100 RON/ha for chisel-based systems and 195-200 RON/ha for rotary harrow systems. Over a 10-year period, this corresponds to cumulative savings of roughly 1,000-1,950 RON/ha, representing a significant reduction in direct production costs, particularly for large-scale farms.

In addition to fuel savings, minimum tillage substantially improves operational efficiency. Studies indicate reductions of 55-65% in working time per hectare compared to conventional tillage, due to fewer field passes and higher work productivity (Gîngu et al., 1999). Fewer operating hours also result in lower labor costs and reduced machinery depreciation. Moreover, the reduced number of operations increases the likelihood of completing seedbed preparation and sowing within optimal agrotechnical windows, which is critical in southern Romania where rainfall

distribution is irregular and soil drought may occur rapidly (Jităreanu et al., 2009b).

Crop yield responses under minimum tillage are generally comparable to those under plowing when management is adequate. Multiannual experiments on chernozems and preluvosols show that yields of wheat, soybeans and rapeseed remain statistically similar, while maize yields may decrease slightly (92-98% of the control) in certain minimum tillage variants (Cociu, 2011; Moraru et al., 2015). However, these modest yield reductions are often offset by lower production costs per ton. In addition, residue retention and reduced soil disturbance enhance soil moisture conservation, contributing to greater yield stability in dry years (Filip et al., 2024).

From a long-term perspective, minimum tillage positively affects soil fertility. Studies from southern Romania report improved pH stability, higher humus content in the topsoil and a more balanced distribution of nutrients compared to conventional plowing, which accelerates organic matter mineralization and

soil acidification (Cociu, 2011). Higher biological activity under reduced tillage further supports nutrient cycling and soil resilience, potentially lowering future costs for corrective amendments.

CONCLUSIONS

The analysis of chemical indicators shows that the conservation tillage system maintains soil chemical balance through moderate and stable values of pH, humus content and nutrient elements, thus supporting soil resource conservation and long-term sustainability in the Afumați area.

Conventional soil tillage practices promote the accelerated loss of organic matter and nutrients by intensifying mineralization and leaching processes. This leads to a decline in soil fertility and increases the vulnerability of the agricultural system to extreme climatic conditions, such as drought, high temperatures, or excessive rainfall, particularly in the Mavrodin area.

The comparative analysis between the conservation tillage system (no-till) and the conventional tillage system in the third study area highlights significant differences in terms of soil chemical properties and nutrient dynamics. The no-till system demonstrates clear advantages in maintaining a higher organic matter content in the surface layer, as well as a more stable pH profile, with slight alkalization in the deeper horizons. Although it shows moderate to low levels of available nutrients, particularly phosphorus and potassium, the conservation system provides a more favorable environment for nutrient retention and for maintaining long-term soil quality, due to reduced mechanical disturbance and the presence of surface plant residues.

In contrast, the conventional tillage system offers higher initial nutrient availability, especially nitrogen and phosphorus, but these levels decline more rapidly over time, likely due to mechanical disruption, leaching, and mineralization losses. This system also exhibits less stable pH values and a lower organic matter content in the upper layer,

which may negatively affect soil fertility and resilience, particularly under the increasing pressure of climate variability observed in the third study area.

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