Soil nutrients and carbon sequestration: Usual practices in the Central region of Romania

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Abstract. This study aimed to analyze soil organic carbon (SOC) and nutrient dynamics (N, P, K) under conventional and organic farming systems in maize cultivation and pasture management across farms in Alba and Bistrița-Năsăud counties, Romania. Soil samples were collected from the A horizon and analyzed for pH, nutrients, and SOC content. The results revealed that organic systems consistently enhanced humus and carbon levels, emphasizing their role in improving soil organic matter. Conventional systems exhibited higher phosphorus, potassium, and soluble salt levels, primarily due to synthetic fertilizer use. Correlation analysis highlighted the interconnectedness of soil properties, with SOC strongly linked to humus and nutrient availability. Organic practices improved long-term soil stability and fertility, while conventional systems provided higher immediate nutrient availability.
Key Words: conventional and organic farming, correlation, nitrogen, phosphorus, potassium.

Introduction. Soil serves as a vital reservoir for carbon, storing more carbon than the atmosphere and vegetation combined. The balance of soil nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), is critical for optimizing carbon sequestration while maintaining soil fertility (Bradford et al 2008; Kirkby et al 2024; Tipping et al 2016). Factors influencing soil organic carbon (SOC) storage include land use, vegetation, and management practices (He et al 2024). Effective soil nutrient management is pivotal for enhancing carbon sequestration, supporting food security, and mitigating climate change. Research developments are needed to refine sustainable practices that optimize both soil nutrient dynamics and carbon storage across diverse ecosystems (Baveye & Wander 2019; Crowther et al 2016).

Nutrients, especially N and P, are essential for plant growth and biomass production, which are precursors to SOC. Imbalanced nutrient levels can limit plant productivity and microbial efficiency, reducing carbon storage potential (Fontaine et al 2007; Parton et al 1988). Adequate nutrient availability enhances plant biomass, leading to increased organic inputs to soil (Chenu et al 2019).

Excessive fertilization, particularly with N, can accelerate organic matter decomposition, potentially offsetting carbon storage gains. Nutrient levels affect the composition and activity of soil microbes, which regulate the decomposition and stabilization of organic matter (Han et al 2016; Jones et al 2013; Sanderman et al 2014). Practices such as crop rotation, cover cropping, and organic amendments improve nutrient cycling and SOC storage. Over-reliance on synthetic fertilizers in conventional systems can lead to nutrient imbalances, soil degradation, and reduced carbon sequestration potential.

The aim of the current study was to identify the nutrients and carbon content in soils collected from vegetal farms cultivating maize and pastures in two different systems, conventional, and organic, respectively, and their interactions, in order to emphasize the influence of crops and soil working systems on soil nutrients, and carbon sequestration.

Material and Method. The research was carried out in 2024, on private farms, two located in Alba County, and two in Bistrița-Năsăud County, Romania. The farms located in Alba County are vegetal farms. Both are destined to cereal cultivation, but one applies the conventional system, while the other the organic system. The farms located in Bistrița-Năsăud County have in possession natural pastures, and the same, in one farm is practiced the conventional system, while in the other the organic system. Soil samples were collected from each farm, from the A horizon, using a soil probe. The laboratory analysis consisted in the quantification of the soil pH using potentiometry, nutrients (N, P, K, using spectrometry and flamphotometry), total organic carbon and residual, using the gravimetric method. Data were statistically processed using SPSS for Windows. Basic statistics was used for emphasizing the means, the parameters of dispersion, and simple Pearson correlations.

Results and Discussion. Differences in soil nutrients content are observed under conventional and organic maize cultivation systems (Table 1). Soil pH values are similar across both systems, with no significant differences observed. Organic cultivation shows higher humus and carbon content, suggesting improved soil organic matter, while conventional farming exhibits higher phosphorus, potassium, and soluble salt levels, likely due to synthetic fertilizer use. Nitrogen levels are slightly higher in organic soils, but not significantly different. These results show the differences between organic practices enhancing organic matter and conventional methods maintaining higher readily available nutrient levels.

A strong positive correlation is observed between soil carbon and humus content (0.72), phosphorus (0.98), potassium (0.78), and soluble salts (0.94), suggesting that higher soil carbon is associated with increased organic matter and nutrient availability. Soil pH shows a negative correlation with most variables, notably nitrogen (-0.85), potassium (-0.54), and soluble salts (-0.56), indicating that lower pH may align with higher nutrient concentrations. Humus content exhibits patterns similar to soil carbon, reinforcing the relationship between organic matter and nutrient dynamics. Overall, these correlations emphasize the interconnectedness of soil properties in influencing nutrient availability and soil fertility under conventional practices (Table 2).

Under organic maize cultivation, soil carbon shows strong positive correlations with humus (0.85) and negative with pH (-0.73), indicating that higher soil carbon is associated with improved organic matter and slightly lower pH levels. However, soil carbon negatively correlates with phosphorus (-0.72), potassium (-0.23), and soluble salts (-0.29), suggesting an inverse relationship with certain nutrient concentrations. Soil pH displays positive correlations with humus (0.73) but a notable negative correlation with soluble salts (-0.67), indicating that lower salt levels are linked with higher pH. Nitrogen correlates strongly with potassium (0.97) and phosphorus (0.51), highlighting nutrient interdependence, while showing a negative correlation with soluble salts (-0.68). Phosphorus negatively correlates with carbon (-0.72) and humus (-0.72), but positively with potassium (0.60), suggesting potential competition or distinct nutrient dynamics in organic systems. These correlations emphasize the unique nutrient relationships in organic soils, highlighting the role of organic matter and soil pH in influencing nutrient availability (Table 3).

Table 1

The descriptive statistics for soil pH and nutrients content corresponding to maize cultivation, when conventional and organic practices are used

Crop	*Cultivation system*	*N*	*X*	*s*	*CV, %*
pH	Conventional	5	7.28^a	0.19	2.61
pH	Organic	5	7.00^a	0.08	1.18
Humus, %	Conventional	5	3.66^a	0.47	12.73
Humus, %	Organic	5	4.32^b	0.19	4.45
C, %	Conventional	5	2.02^a	0.26	12.73
C, %	Organic	5	4.87^b	0.19	3.95

Crop	Cultivation system	N	X	s	CV, %
N, %	Conventional	5	0.18[a]	0.01	4.44
N, %	Organic	5	0.23[a]	0.02	10.49
P, mg kg^{-1}	Conventional	5	125.35[a]	3.87	3.09
P, mg kg^{-1}	Organic	5	73.50[b]	3.00	4.08
K, mg kg^{-1}	Conventional	5	261.68[a]	8.09	3.09
K, mg kg^{-1}	Organic	5	191.89[b]	2.56	1.33
Soluble salts, mg 100 g^{-1}	Conventional	5	100.93[a]	2.74	2.72
Soluble salts, mg 100 g^{-1}	Organic	5	14.57[b]	1.13	7.75

Different letters correspond to significant differences at 5% threshold.

Table 2

The simple Pearson correlations between soil carbon, soil pH, and soil nutrients, corresponding to maize cultivation, in conventional system

	C, %	*pH, units*	*Humus, %*	*N, %*	*P, mg kg^{-1}*	*K, mg kg^{-1}*	*Soluble salts, mg 100 g^{-1}*
C, %	1.00	-0.30	0.72	0.71	0.98	0.78	0.94
pH, units	-0.30	1.00	-0.30	-0.85	-0.26	-0.54	-0.56
Humus, %	0.72	-0.30	1.00	0.71	0.98	0.78	0.94
N, %	0.71	-0.85	0.71	1.00	0.67	0.87	0.83
P, mg kg^{-1}	0.98	-0.26	0.98	0.67	1.00	0.81	0.91
K, mg kg^{-1}	0.78	-0.54	0.78	0.87	0.81	1.00	0.75
Soluble salts, mg 100 g^{-1}	0.94	-0.56	0.94	0.83	0.91	0.75	1.00

When soil corresponding to pasture maintaining is analyzed in both organic and conventional systems, pH is similar across systems, with no significant differences (6.24 for conventional and 5.94 for organic). Organic management shows higher humus content (4.42% vs. 3.57%) and carbon levels (2.43% vs. 1.96%), reflecting improved organic matter under organic practices. However, conventional systems exhibit higher nitrogen (0.61% vs. 0.31%), phosphorus (73.88 mg kg^{-1} vs. 61.20 mg kg^{-1}), potassium (184.36 mg kg^{-1} vs. 154.00 mg kg^{-1}), and soluble salts (11.41 mg 100 g^{-1} vs. 8.40 mg 100 g^{-1}), suggesting greater nutrient availability due to synthetic inputs. These results highlight trade-offs, with organic practices enhancing organic matter but conventional systems maintaining higher immediate nutrient availability (Table 4).

Table 3

The simple Pearson correlations between soil carbon, soil pH, and soil nutrients, corresponding to maize cultivation, in organic system

	C, %	*pH, units*	*Humus, %*	*N, %*	*P, mg kg^{-1}*	*K, mg kg^{-1}*	*Soluble salts, mg 100 g^{-1}*
C, %	1.00	-0.73	0.85	0.45	-0.72	-0.23	-0.29
pH, units	-0.73	1.00	0.73	-0.47	-0.36	0.25	-0.67
Humus, %	0.85	0.73	1.00	0.88	-0.72	-0.23	-0.29
N, %	0.45	-0.47	0.88	1.00	0.51	0.97	-0.68
P, mg kg^{-1}	-0.72	-0.36	-0.72	0.51	1.00	0.60	0.21
K, mg kg^{-1}	-0.23	0.25	-0.23	0.97	0.60	1.00	-0.62
Soluble salts, mg 100 g^{-1}	-0.29	-0.67	-0.29	-0.68	0.21	-0.62	1.00

Table 4

The basic statistics for soil pH and nutrients content corresponding to pasture maintaining, when conventional and organic practices are used

Crop	*Cultivation system*	*N*	*X*	*s*	*CV, %*
pH	Conventional	5	6.24a	0.14	2.26
pH	Organic	5	5.94a	0.42	7.08
Humus, %	Conventional	5	3.57a	0.10	2.91
Humus, %	Organic	5	4.42b	0.32	7.32
C, %	Conventional	5	1.96a	0.06	2.91
C, %	Organic	5	2.43b	0.18	7.32
N, %	Conventional	5	0.61a	0.09	14.75
N, %	Organic	5	0.31b	0.01	3.47
P, mg kg^{-1}	Conventional	5	73.88a	3.27	4.42
P, mg kg^{-1}	Organic	5	61.20b	1.92	3.14
K, mg kg^{-1}	Conventional	5	184.36a	5.03	2.73
K, mg kg^{-1}	Organic	5	154.00b	3.16	2.05
Soluble salts, mg 100 g^{-1}	Conventional	5	11.41a	2.31	20.21
Soluble salts, mg 100 g^{-1}	Organic	5	8.40b	1.14	13.57

Different letters correspond to significant differences at 5% threshold.

Unlike our results, Jobbágy & Jackson (2004) reported higher soil K content (but expressed in g/m^2) when crops are cultivated (81 g/m^2) compared with pastures (115 g/m^2).

In conventional systems, soil carbon shows moderate negative correlation with pH (-0.47), but positive with nitrogen (0.65), suggesting a relationship between higher carbon levels and improved soil nitrogen content and decreased pH. Similarly, pH correlates negatively with nitrogen (-0.65), indicating the pH's role in influencing nitrogen availability. Humus content exhibits weaker correlations, showing a slight positive association with soil carbon (0.26) and pH (0.26), but a notable negative correlation with phosphorus (-0.59), reflecting potential nutrient trade-offs in soils with high organic matter. Nitrogen and potassium display a negative relationship (-0.64), suggesting an inverse interaction in their soil dynamics.

Soluble salts correlate strongly with carbon (1.00) and pH (1.00), highlighting their close relationship under conventional practices. Potassium shows minimal correlations with most variables, indicating its distinct behavior in the soil system. Overall, the correlations emphasize the interdependence of soil properties, with carbon, pH, and nitrogen closely linked under conventional pasture systems (Table 5).

Table 5

The simple Pearson correlations between soil carbon, soil pH, and soil nutrients, corresponding to pasture maintaining, in conventional system

	C, %	*pH, units*	*Humus, %*	*N, %*	*P, mg kg^{-1}*	*K, mg kg^{-1}*	*Soluble salts, mg 100 g^{-1}*
C, %	1.00	-0.47	0.26	0.65	0.41	-0.15	1.00
pH, units	-0.47	1.00	0.26	-0.65	0.41	-0.15	1.00
Humus, %	0.26	0.26	1.00	0.82	-0.59	-0.10	0.26
N, %	0.65	-0.65	0.82	1.00	0.13	-0.64	0.65
P, mg kg^{-1}	0.41	0.41	-0.59	0.13	1.00	0.37	0.41
K, mg kg^{-1}	-0.15	-0.15	-0.10	-0.64	0.37	1.00	-0.15
Soluble salts, mg 100 g^{-1}	1.00	1.00	0.26	0.65	0.41	-0.15	1.00

Table 6 illustrates the Pearson correlations between soil carbon, pH, humus, nitrogen, phosphorus, potassium, and soluble salts in soils under organic pasture maintenance. Soil carbon shows a positive correlation with nitrogen (-0.66), but negative phosphorus (-0.71), and potassium (-0.52), suggesting that higher organic matter might coincide with reduced availability of these nutrients, possibly due to slower nutrient release.

Table 6

The simple Pearson correlations between soil carbon, soil pH, and soil nutrients, corresponding to pasture maintaining, in conventional system

	C, %	*pH, units*	*Humus, %*	*N, %*	*P, mg kg^{-1}*	*K, mg kg^{-1}*	*Soluble salts, mg 100 g^{-1}*
C, %	1.00	-0.24	0.23	0.66	-0.71	-0.52	0.29
pH, units	-0.24	1.00	-0.82	-0.22	0.60	-0.39	-0.79
Humus, %	0.23	-0.82	1.00	0.40	-0.20	0.68	0.31
N, %	0.66	-0.22	0.40	1.00	0.48	0.79	-0.22
P, mg kg^{-1}	-0.71	0.60	-0.20	0.48	1.00	0.49	-0.84
K, mg kg^{-1}	-0.52	-0.39	0.68	0.79	0.49	1.00	-0.14
Soluble salts, mg 100 g^{-1}	0.29	-0.79	0.31	-0.22	-0.84	-0.14	1.00

A slight positive correlation with soluble salts (0.29) indicates a minor relationship between carbon content and salt levels. Soil pH negatively correlates with humus (-0.82) and soluble salts (-0.79) but positively with phosphorus (0.60), highlighting its role in nutrient dynamics and salt behavior. Humus content is positively associated with nitrogen (0.40) and potassium (0.68), showing its contribution to nutrient retention and cycling. Nitrogen correlates positively with phosphorus (0.48) and potassium (0.79), reflecting nutrient interdependence, while phosphorus negatively correlates with soluble salts (-0.84), suggesting an antagonistic relationship. Potassium exhibits a positive association with nitrogen and humus but a weak negative relationship with soluble salts (-0.14). Overall, the correlations reveal complex nutrient interactions in organic pasture soils, with organic matter, pH, and salts playing key roles in shaping soil nutrient availability (Table 6). Similarly with our results, Zhou et al (2019) reported that soil C and N are negatively correlated with soil pH, and according to their opinion, this indicates a close relationship between soil C and N, on one hand, and pH on the other hand.

Conclusions. In both conventional and organic systems, higher soil carbon is strongly linked to increased humus content, highlighting the importance of organic matter in soil carbon dynamics. Organic systems consistently showed higher humus and carbon levels, emphasizing the role of organic practices in enhancing soil organic matter. Soil pH influences nutrient availability differently across systems. In conventional systems, pH shows a positive relationship with nitrogen and phosphorus, suggesting its role in nutrient solubility. However, in organic systems, pH is more closely tied to humus and soil carbon, reflecting the buffering capacity of organic matter. Nitrogen, phosphorus, and potassium display strong interdependencies, especially in organic systems. Conventional systems tend to have higher phosphorus and potassium levels, likely due to synthetic inputs, while organic systems exhibit slower nutrient release, which may reduce immediate availability but could improve long-term soil fertility. Conventional systems often have higher levels of soluble salts, reflecting the use of fertilizers. In organic systems, soluble salts are generally lower, contributing to reduced salinity risks but potentially influencing nutrient solubility and plant uptake. Organic practices enhance soil health by increasing organic matter and stabilizing pH, but conventional systems maintain higher immediately available nutrient levels, such as phosphorus and potassium. These differences suggest a trade-off between long-term soil health and short-term nutrient availability. Organic practices promote long-term soil stability and ecological balance by enhancing organic matter and reducing dependency on external inputs. Conventional practices, while effective for immediate nutrient supply, may lead to challenges such as soil degradation or nutrient imbalances over time. The choice between systems should align with the specific goals of agricultural management.

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Conflict of interest. The authors declare no conflict of interest.

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