11th INTERNATIONAL SOIL CONGRESS

CAPPADOCIA, TÜRKİYE 2024

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PROCEEDINGS

11th INTERNATIONAL SOIL CONGRESS 2024

Challenge Soil Threats Save Your Future Horizon

SOILSAFE 2024

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EDITORS

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PREFACE

The Soil Science Society of Türkiye was established in 1964 as a non-governmental organization to advance, disseminate, and promote soil science in both theoretical and applied fields across Türkiye. The Society, which operated without any political affiliation, had 920 members from academic and research backgrounds. It engaged in various activities to raise awareness that soil is a vulnerable and irreplaceable resource that must be protected. Among these efforts, one key activity was the biennial international congress organized by the Society.

The Soil Congress is one of the most prominent and extensive congresses in the field of Soil Science. The 11th Soil Congress was held in Nevşehir as part of the Soil Science Society of Türkiye's commitment to organizing this event every two years. Under the theme "Confront Soil Threats, Secure Your Future Horizon," the primary goal of these congresses was to address the pressing challenges and prospects for soil.

During the 11th Soil Congress, a wide range of topics was covered, from recent developments in soil science worldwide and in Türkiye to scientific and technological advancements. Sessions were held to discuss research findings, legal regulations, and structural frameworks. This congress served as a valuable platform for young academics and researchers to meet field experts, network with each other, and engage with representatives from relevant Ministry Directorates, Research Institutes, Universities, and Non-governmental Organizations within Türkiye.

Additionally, the congress provided an excellent opportunity to explore the social and cultural heritage of Cappadocia through organized activities beyond the scientific program. Events like this proved invaluable for sharing research and generating new ideas, and it was hoped that the knowledge shared at this congress would make a lasting contribution to the scientific community and support the ongoing success of soil science.

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FULL TEXT

An Innovative and Cost-effective Approach to Simulate Crust Strength for Wind Erosion Studies

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ABSTRACT

Wind erosion is known as one of the dominant land degradation processes in terms of the sustainability of natural resources in semi-arid and arid regions of the world. Soil crusts form a protective layer on the soil surface, reducing the probability of particle detachment by erosive winds. A well-developed crust increases the threshold wind speed necessary to initiate soil particle movement, thereby reducing the risk of wind erosion. However, weak or fragile crusts can break down into smaller particles under wind stress, contributing to dust emission. Thus, crust strength is crucial factor for assessing wind erosion. Prediction models like the Wind Erosion Prediction System (WEPS) or Revised Wind Erosion Equation (RWEQ) use crust strength data to simulate erosion risk under different scenarios, helping land managers make informed decisions. Wind tunnels, while highly effective for studying wind erosion, can indeed be time-consuming and costly to operate. They require large infrastructure, precise control of environmental variables, and can take significant time to set up and run experiments. Given these challenges, small experimental units or alternative methods can be more appropriate for certain studies. A reliable method to measure soil crust strength under erosive winds could greatly enhance efforts to prevent wind erosion and improve prediction models for managing these vulnerable ecosystems. In this study, we aimed to introduce an innovative approach to quantify how well different crusts resist erosion under varying wind speeds and particle sizes by simulating saltation transport mechanism to improve prediction models and apply more effective soil conservation strategies.

Keywords: Crust strength, saltation, soil crust; wind erosion

INTRODUCTION

Soil crusts can significantly reduce water infiltration, increase surface runoff, and delay or impede seed germination, particularly in bare soils. These crusts form naturally through a combination of physical, chemical, and biological processes. The formation of physicochemical crusts is primarily driven by two key mechanisms: (i) the physical disintegration of soil aggregates due to wetting and the impact of raindrops, and (ii) the physicochemical dispersion of soil particles. As a result, a denser and less permeable upper soil layer develops compared to the layers beneath, due to the combined effects of physical breakdown and chemical dispersion of aggregates (Agassi et al., 1988; Assouline, 2011; Yan et al., 2015; Hou et al., 2020).

Saltation, where particles are lifted and bounce along the surface, is the dominant mechanism of wind-driven sediment transport, accounting for 50–90% of sediment movement (Ishizuka et al., 2008). The effect of soil crusts on wind erosion processes presents a potentially beneficial situation, as crusts can limit the release of fine particles into the atmosphere by reducing saltation. Detachment of particles from a crusted surface is more complex, as additional force is required from the impacting grains to dislodge particles from the crust. The crust's resistance to particle detachment, or its detachment potential, plays a critical role in the initiation of saltation.

A reliable method to measure the strength of dried soil crusts against to saltation process could greatly enhance efforts to prevent wind erosion and improve predictive models, which is crucial for managing of vulnerable ecosystems. Soil crust strength measurements under erosive wind conditions typically involve wind tunnel experiments using soil trays with crusted surfaces formed through wetting and drying cycles. This approach is labor-intensive and provides only broad measurements, such as wind speed, the rate of added saltating particles, and net soil loss during the erosion event. However, it lacks precise data on the amount, impact angle, and velocity of the abrasive particles responsible for soil detachment. Even with sophisticated velocity and particle tracking instrumentation in wind tunnel measurements, the variability in impacting particle size, and velocity field makes it difficult to integrate over the entire testing surface during the erosive event. Besides using a wind tunnel, other soil crust and aggregate stability measurement techniques measure resistances against crushing, penetration, rapture, and shear stresses and they only represent some components of the particle impact-detachment failure mechanism during wind erosion (Deviren Saygin and Huang, 2022).

Developing a simple, accurate, and reliable method for directly measuring the strength of different soil crust types under various wind abrasion conditions could greatly contribute to more effective wind erosion prevention and improve wind erosion prediction models (Zobeck et al., 2003; Shao, 2004, 2008; Uzun et al., 2017; Klose et al., 2019). Hagen

(1984) conducted an experiment using the sandblasting technique to directly measure the amount of abraded soil, highlighting a new direction in wind erosion research. In this study we outline the technological development of the sandblasting technique using sensor-based approaches and evaluates its effectiveness as a reliable method for measuring soil crust strength under saltation conditions.

MATERIALS and METHODS

A typical sandblasting device has a sand reservoir, air compressor with air pressure regulator, solenoid valve, and a timer circuit to regular the blasting time. Deviren Saygin and Huang (2022) presented a schematic diagram of a basic sandblasting setup (Fig. 1). This device was designed in accordance with the sandblasting technique reported by Hagen (1984) which is considered a methodological pre-prototype. In test area, they used a platform which holds the soil ring to adjust splash angle for saltation process, and air pressure was set up as 2.95 kg cm-2. The testing procedure involved setting the blasting time, weighting the soil ring, position the ring under the blasting nozzle, blasting, and weighing the soil ring again to calculate the amount of soil loss. In saltation stage, white silica sand ranges between 0.6 mm and 0.71 mm in diameter was blasting at a rate of 0.18 g s-1 till the crust was broken under simulated wind-blow in setup.

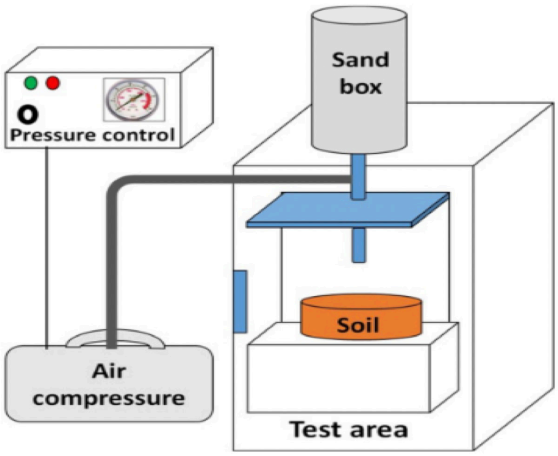

Figure 1. Schematic Diagram of Sandblasting Setup (Deviren Saygin and Huang, 2022)

Since their experiment was only conducted with vertical blasting for limited soil types, they recommended to test this technique for different impacting angles and particle splash speeds to more accurately simulate situations under wind erosive conditions for a wide range of soil types. The next step, we tried to improve this prototype with a state of art approach to overcome mentioned limitations of performing crust strength in chancing external conditions. Thus, we planned to design a more friendly and innovative prototype, and conducted a research study (Deviren Saygin et al., 2022). This version of the prototype was seen in Fig. 2.

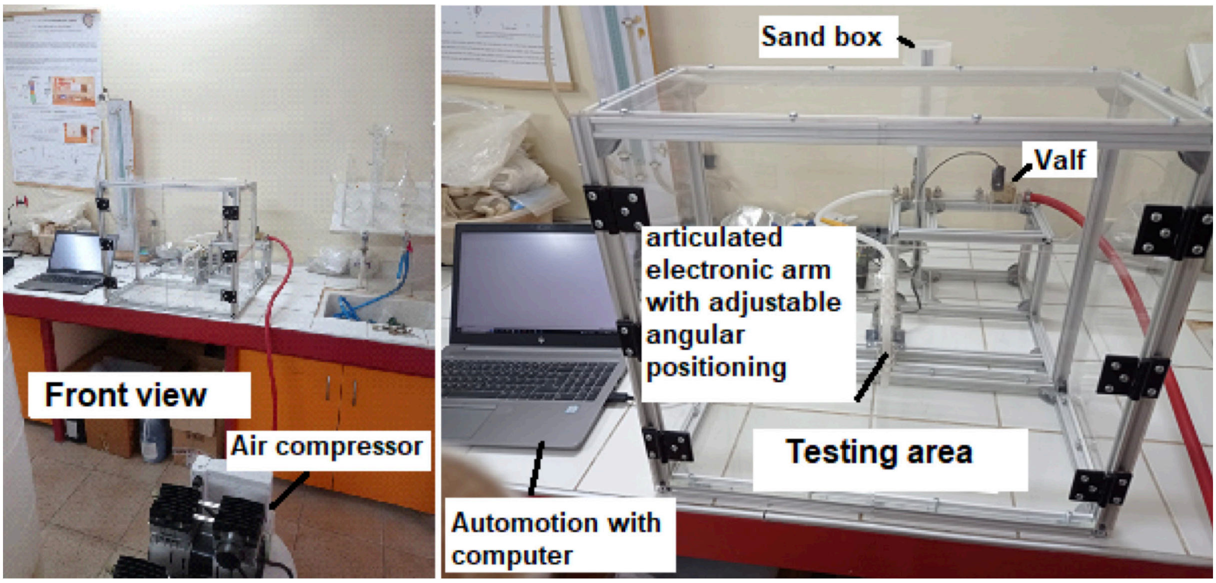

Figure 2. Innovative Sandblasting Setup Prototype (Deviren Saygin et al., 2022)

In this prototype, unlike the pre-prototype, an Arduino electronic platform with open-source, user-friendly hardware and software has been utilized to create highly interactive electronic systems. These systems enable variation in energy flow, impact duration, and changes in the angles at which particles splash onto the soil surface. In summary, a saltation simulator has been developed and tested, allowing the measurement of changes in crust strength under saltation conditions. The simulator can be adjusted for different impact angles and sand flow rates, while also monitoring and controlling the soil or crust surface changes caused by erosion.

RESULTS and DISCUSSION

Sandblasting technique was used to measure soil crust stability under chancing abrasion conditions for two silt loam soil types with the designed device as presented in Fig. (1). The indings stated that this prototype has a high potential to reflect changes in intrinsic soil conditions. And, it was very sensitive to reflect the changes in soil management history in terms of soil organic carbon content, despite the bulk soil properties were similar. But authors stated that the method and the designed setup were open to development for more realistically modeling the variations in crust sensitivities under saltation conditions. To make more reliable simulations this technique was improved in terms of splash angle setup, variation of blasting rates to enable real-time monitoring of changes in crust strengths (Fig. 2). The new prototype is an improvement over the previous version, but it still has several limitations that affect the accuracy of simulations in the testing area. For ongoing studies involving simulations on both crusted soils and natural surface conditions, it is necessary to integrate a system that can monitor particle splash distances within the test area. Calibrating the results obtained from tunnel experiments will strengthen the accuracy of the findings. While this technique demonstrates higher sensitivity and suitability for measuring crust strength compared to other mechanical force-based methods, it must be evaluated under various soil conditions, with a thorough investigation into its overall sensitivity.

CONCLUSION

This study demonstrated that a simple device could quickly quantify the erodibility of soil surfaces or aggregates under the impact of wind-driven grains according to sandblasting technique. Although the device has been successfully evaluated in simulating varying soil conditions with respect to crust strength, there are still aspects of the technique that can be improved. To address these, future developments will focus on: extending the test area, incorporating sensors to monitor particle transport distances, and implementing sensor-based measurements of particle impact velocities. Additionally, a lidar device, which is currently positioned outside the system, will be integrated to allow real-time monitoring of changes in surface topography.

ACKNOWLEDGMENTS

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Determination of Soil Quality Index for Tea Plant based on the Best-Worst Method

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ABSTRACT

The objective of this study is to determine the soil quality index using multi-criteria decision making and standard scoring functions with the help of geographic information systems by taking into account the physical, chemical, fertility and biological properties of soils distributed in a micro-catchment area within the borders of Rize Province, where intensive tea cultivation is practiced. A total of one hundred and two soil samples were collected from tea gardens according to the FAO/WRB classification, including the predominant major soil groups Leptosol and Alisol-Acrisols. In the Soil Quality Index (SQI) model, soil indicators were weighted using the Best Worst Method (BWM). Various indicator units were normalized using the standard scoring function. The SQI model for the tea plant included five main criteria: physical, chemical, fertility (micro and macro nutrients), biological, and erosion susceptibility parameters of the soil, along with thirty-two sub-criteria under these main criteria. The results indicated that the soil quality within the study area ranged from 0.28 to 0.68, with an average value of 0.51. To facilitate the visualization of these results, soil quality distribution maps were prepared in a GIS environment.

Keywords: Best-worst method, GIS, soil parameters, soil quality index, tea plant

INTRODUCTION

The expansion of the global population over recent decades has placed increasing pressure on agricultural lands for the production of crops. This has led to the indiscriminate use of soil and water resources. The deterioration of agricultural lands due to various issues has the effect of reducing their quality, thereby limiting the effective and sustainable use of these lands. This, in turn, has the adverse effect of affecting biodiversity, contributing to the degradation and even disappearance of vital resources worldwide, such as water, soil, and air. It is of the utmost importance to determine, monitor, and implement the necessary measures for their destruction in a timely manner through reliable methods. In this context, the continuous and adequate fulfilment of the physical, chemical, and biological functions of soil for plants is referred to as "soil quality". The concept of soil as a dynamic living system, continuously performing its biological, physical, and chemical functions, is a fundamental tenet of soil science. This system is explained by a unique balance and interaction among biological, physical, and chemical components (Karlen et al., 1997).

The establishment of a sustainable agricultural ecosystem is contingent upon the reliability and pervasive applicability of the methods employed to ascertain soil quality, thereby ensuring that requisite needs are met without negatively impacting environmental components in the present and in the future. Two distinct concepts exist with regard to the concept of soil quality in the present era (Karlen et al., 1997; Seybold et al., 1999). The first concept is the capacity of soil characteristics as a function (Doran and Parkin, 1994), while the second is the concept of suitability for use (Larson and Pierce, 1994; Acton and Gregorich, 1995). The objective of soil quality studies is to monitor and evaluate the effects of soil tillage and other management practices on the physical, chemical, and biological properties of soil. This is achieved by utilising these properties as tools to examine the potential and current status of soils. The implementation of new agricultural practices over time has the potential to alter the physical, chemical, and biological properties of the soil. In light of these changes, it is evident that soils, a natural resource, are unable to sustain indefinite production. It is essential to ensure that the use and management of soils are balanced and planned, and that any changes are monitored. This is particularly important given the structure and usage area of the soil in question. Consequently, decisions regarding land use should be made not only on the basis of land suitability assessments, but also in consideration of social (demand for products from different sectors), economic, and environmental factors.

Geographic Information Systems (GIS) are employed in the storage, processing, and visual representation of numerous spatial inputs or outputs, thereby facilitating the provision, processing, and conversion of these inputs into decision- or support-oriented tools. Remote sensing and GIS information technologies offer significant opportunities for the identification of factors that restrict cultivation, such as the sustainable and efficient use of our agricultural land resources. The utilisation of data obtained through remote sensing and GIS in the determination of soil quality allows for a more precise observation of changes in quality, thereby ensuring the preservation of soil with early intervention and a reduction in expenses and spending.

A variety of methods are employed to ascertain soil quality (Özulu et al., 2006; Valani et al., 2020; Adetunji et al., 2020; Lal, 2020), including Multi-Criteria Decision Making (MCDM) techniques. Among these techniques, the Best-Worst Method (BWM), introduced recently by Rezaei (2015), offers a reduction in the number of pairwise comparisons compared to other MCDM techniques like AHP, thereby providing more consistent comparisons. The well-structured pairwise comparison system of BWM yields more reliable findings, offering significant advantages such as rapid computation and simplicity for experts, particularly in scenarios involving numerous indicators (Ahmadi et al., 2017; Singh et al., 2021). The notable features of BWM have led to its successful application in a number of fields (Hashemizadeh et al., 2020; Torkayesh et al., 2021).

However, to the best of the authors' knowledge, scientific studies on the assessment of soil quality using BWM for agricultural crops are relatively scarce. Consequently, the present study employed BWM to ascertain the soil quality of a micro-catchment situated in Rize province, a region of Turkey located in the Black Sea. The study area is notable for its prevalence of tea cultivation. The results were used to create maps of soil quality distribution in a geographic information system (GIS) environment.

MATERIAL and METHOD

Description of Study Area

Rize province is located between longitudes 40° 21' and 41° 25' E and latitudes 40° 33' and 41° 20' N (Fig. 1). The province has an area of 3920 km2, being mostly mountainous. Rize province is surrounded by Trabzon in the west, Erzurum and Bayburt in the south, Artvin in the east and the Black Sea in the north.

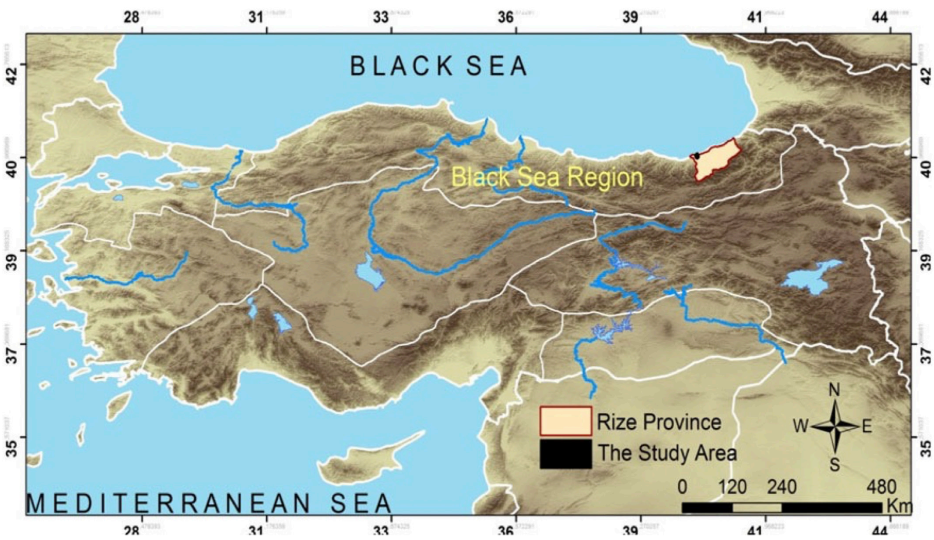

Figure 1. Location map of the study area

The study area was a micro-catchment in Rize province with an area of approximately 1671.8 ha and an altitude between 0 and 862 m above sea level. The micro-catchment has a mountainous and rugged topography and the slope varies widely (Fig. 2). The southwestern parts of the area have lands with gentle to moderate (6– 12%) slopes. However, most of the south-eastern and northern regions have steeper slopes, turning into a steep topography further these directions. Also, the slope exposure is toward the northeast and east in most of the area. The areas to the northeast and east of the riverbed have an exposure toward the north-west and east. Considering geological content, most of the micro-catchment consists of volcanic sedimentary rocks, with a mixture of sandstone-mudstone-limestone in the southeast. Red yellow podzolic soils are distributed throughout the area. These soils are classified as Alisol-Acrisol according to FAO-WRB (2014). Most of the micro-catchment is used for tea cultivation and few lands.

Soil Sampling and Analysis

A total of 102 soil samples were collected from the surface (0-20 cm) within the micro-catchment in such a way that the distribution was as homogeneous as possible. The pattern of soil sampling is shown in Figure 2. In addition, soil samples were taken to account for different topographic positions and land use/land cover types (tea plantation).

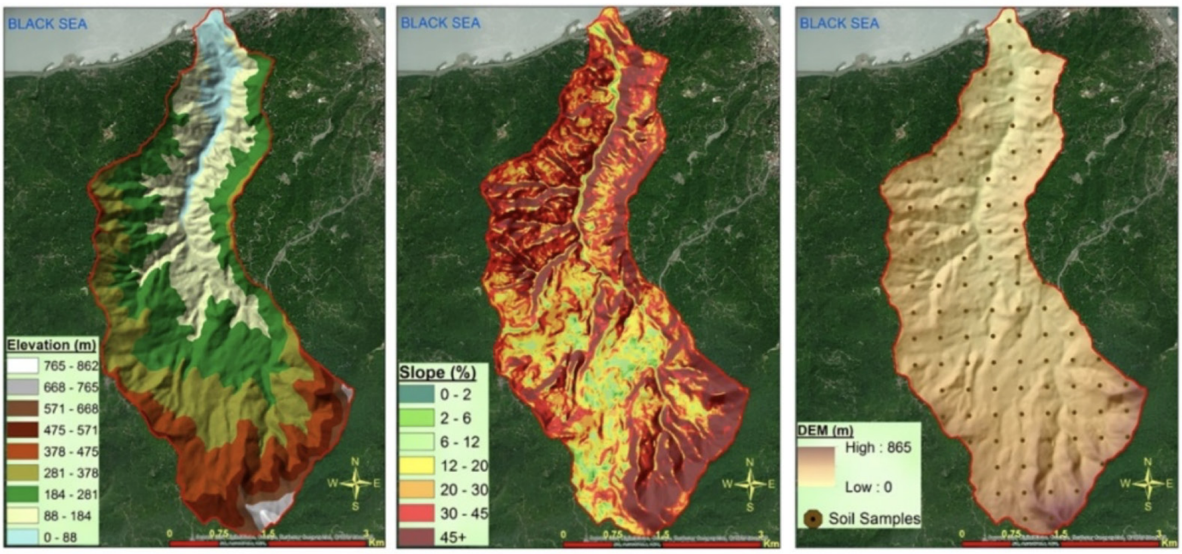

Figure 2. Elevation, Digital Elevation Model (DEM), slope and soil samples maps of the Micro-catchment

The soil samples were separated from coarse particles, airdried under laboratory conditions and sieved through a 2mm sieve. Soil quality status can be evaluated through primary indicators of soil quality that are integrated with soil's physical, chemical and biological properties (Anup and Ghimire, 2019). After they were ready for analysis, we analysed 35 soil quality parameters including physical, chemical and biological properties, plant nutrients and erodibility which indicate susceptibility to erosion. In the Best Worst Method Soil Qualiy Index (BWM-SQI), the indicators are grouped under five categories:

- Physical indicators: sand, clay, silt, bulk density (BD), saturated hydraulic conductivity (HC), field capacity (FC) and permanent wilting point (PWP).
- Chemical indicators: organic matter (OM), CaCO3, electrical conductivity (EC), soil reaction (pH), hydrogen ion content (H) and cation exchange capacity (CEC).
- Nutrient indicators: available phosphorus (AvP), total nitrogen (TN), exchangeable potassium (ExK), exchangeable magnesium (ExMg), exchangeable calcium (ExCa), exchangeable sodium (ExNa), available iron (AvFe), available manganese (AvMn), available copper (AvCu) and available zinc (AvZn).
- Biological indicators: MBC (Cmic), basal respiration (CO2), Cmic/CO2 ratio and metabolic quotient (qCO2).
- Soil erodibility factors: Aggregate stability (AS), Dispersion ratio (DR), Erodibility ratio (ER), Structure stability index (SSI), Clay ratio (CR) and Crust Formation (CF).

Weighting Model Based on BWM

The BWM's consider-the-opposite-strategy provides a structured approach to mitigate bias and improve consistency in pairwise comparisons (Rezaei, 2020). A visual representation of this strategyis shown in Figure3.

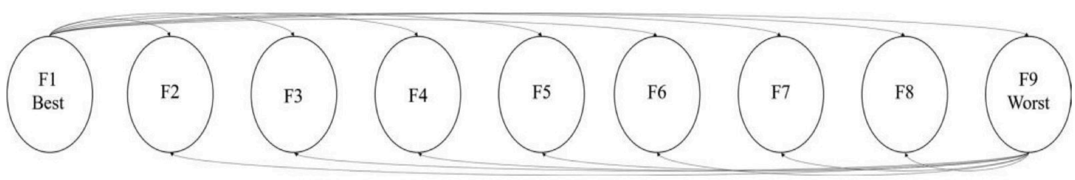

Figure 3. Criteria comparison for BWM (Everest et al., 2021)

1. In the first step, a set of decision criteria are formed;
2. In the second step, the best and the worst criteria aredetermined;
3. In the third step, the best criterion is compared to all the other criteria by using numbers 1 to 9 with $A_B=a_{B1},a_{B2},...,a_{Bn}$ and $a_{BB}=1$;
4. In the fourth step, the worst criterion is compared to other criteria by using numbers 1 to 9 with

   $A_W=a_{1W}, a_{2W}, ..., a_{nW}$ and $a_{WW}=1$;
5. In the fifth step, weights belonging to each criterion areobtained.

For each pairwise comparison, among the best criterion and the others (WB/Wi) and among the worst criteri on and the others (WB/Wi), the optimal weight:

$a_{Bi} = W_B/W_i$ j= 1, 2,......, n

$a_{iw} = W_i/W_w$ j= 1, 2,......, n

When the maximum differences among $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ are solved for all j, the weights are obtained.

This can be defined by the formulation below.

$$\max_{j}\min \left\{ \left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_W} - a_{jW}\right| \right\}$$

So that (1)

$$\sum_{j=1}^{n} w_j = 1 \quad w_j \geq 0, \quad \text{for all } j$$

Formulation (1) took forward solving the problem presented below:

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \quad \text{for all } j$$
$$\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, \quad \text{for all } j \qquad (2)$$
$$\sum_{j=1}^{n} w_j = 1 \quad w_j \geq 0, \quad \text{for all } j$$

The formula (2) can give more than one result if ξ* is not equal to 0, and more than three criteria are evaluated in the problem. The solution to the two linear problems given below must be realized to overcome this and obtain the highest and lowest weights.

$$\begin{aligned}&\min w_j\\&\text{Such that}\\&\left|w_B - a_{Bj}w_j\right| \leq \xi^* w_j\\&\left|w_j - a_j w_w\right| \leq \xi^* w_w\\&\sum_{j=1}^{n} w_j = 1 \quad w_j \geq 0, \quad \text{for all } j\end{aligned} \tag{3}$$

$$\begin{aligned}&\max w_j\\&\text{Such that}\\&\left|w_B - a_{Bj}w_j\right| \leq \xi^* w_j\\&\left|w_j - a_j w_w\right| \leq \xi^* w_w\\&\sum_{j=1}^{n} w_j = 1 \quad w_j \geq 0, \quad \text{for all } j\end{aligned} \tag{4}$$

ξ* indicates objective value of formulation (2).

When formulas (3) and (4) are analyzed for each criterion, values of w^{min*j} and w^{max*j} are formed. The following:

$$w_j = \frac{w_j^{\min*} + w_j^{\max*}}{2} \tag{5}$$

Then the consistency ratio is calculated. The formula (6) given in the following is used for calculation:

$$\text{Consistency Ratio(CR)} = \frac{\xi^*}{\text{Consistency index(CI)}} \tag{6}$$

CI value was obtained from Rezaei (2015).

Where n: number of criteria, A_B: Best to other vector, A_w: Others to worst vector, a_{Bj}: The priority of the best criterion B over criterion j, a_{jW}: The priority of criterion j over the worst criterion W, a_{BW}: The priority of the best criterion B over the worst criterion W, $_{wj}$: The weight of criterion j, $_{w^*j}$: The optimal weight of criterion j.

Standard Scoring Function

The SQI is calculated by combining the results from different types of soil indicators. In this study, nine physical, five chemical, ten productivity, four biological, and five erosion indicators were considered when assessing soil quality. These indicators were selected based on a review of relevant literature, including studies conducted by Demirağ Turan (2019) and Samaei (2022). Due to the wide variety of units for the parameters, a standard scoring function (SSF) (Andrews et al., 2004) was employed for the normalization process, with scores ranging from 0 to 1 being assigned. Based on the degree of their relationship with soil quality, the parameters were divided into two categories: low and high values representing the most desirable soil function (Liebig et al., 2001). First, the parameters of clay, AS, OM, N, P, K, Ca, Mg, Fe, Cu, Mn, Zn, pH, CaCO3, depth, SSI FC, AWC, MBC, soil respiration Cmic/Corg, and CEC were linked to the “more is better” function (MB). Secondly, due to their roles in soil degradation, BD, HC, sand, silt, EC, Na, EO, DR, CF, WP, H, and qCO2 were linked to the “less is better” function (LB).

Soil Quality Determination

Soil properties were weighted with BWM according to their importance level through these comparison matrices. The determined features were converted into comparable unitless scores between 0 and 1 using SSF. The weighted linear combination (WLC) method was used to determine the SQI. The WLC is also defined as weighted estimation, weighted linear mean, or weighted push, and simple additive weighting (Malczewski and Rinner, 2015). This method calculates the soil quality of a potential region using the following formula where SQI represents the soil quality of the agricultural area; Wk: represents the weight of criterion k; aik represents the SSF value of point i within the scope of criterion k, and l represents the total number of criteria.

$$SQI = \sum_{k=1}^{l} w_k a_{ik}$$

RESULTS and DISCUSSIONS

Soil Properties

To determine their quality indices, we examined 35 physical, chemical, productivity, and biological properties in 102 soil samples in a micro-catchment for tea cultivation. Table 1 presents the basic descriptive statistics of these properties. Thirteen were physical quality indicators, with soils often medium to coarse-textured; sand ratios ranged from 41.7% to 79.8% and clay ratios from 4.8% to 36.2%. The mean values for bulk density (BD) and hydraulic conductivity (HC) were 1.3 g/cm^3 and 5.2 cm/h, respectively. Field capacity ranged from 12.0% to 34.6%, while available water-holding capacity ranged from 6.6% to 20.6%. The majority of lands in the micro-catchment exhibited slopes with tea gardens located on them. Due to the high precipitation levels, the soil exhibited increased sensitivity to replacement. The erosion ratio (ER) exhibited a range of 13.7% to 95.7%, while the clay ratio (CR) spanned 4.82% to 36.2%. The average aggregate stability (AS) was 57.5%, dispersion ratio (DR) 34.8%, and structural stability index (SSI) 25.1%. The distributions of silt, ER, DR, SSI, HC, BD, FC, and PWP were found to be normal. Conversely, sand, CR, and AS exhibited negatively skewed distributions, while the remaining properties exhibited positively skewed distributions. The coefficient of variation (CV) indicated high variability for sand, ER, AS, DR, SSI, and HC; moderate variability for silt, FC, and PWP; and low variability for the remaining properties.

A total of 12 chemical quality indicators were selected. The soils exhibited a wide range of acidity, from strongly acidic to slightly acidic. The average pH was 3.9, with electrical conductivity (EC) ranging from 0.04 to 0.7 dS/m. The mean lime content was 1.4%. The hydrogen ion was the dominant ion, with an average concentration of 41.8 cmolc/kg. The total basic cations ranged from 0.7 to 40.8 cmolc/kg, while the base saturation ranged from 1.7% to 83.9%. The variability of CEC, total basic cations, base saturation, and H ion was high, while that of other properties was low. The total nitrogen (TN) concentration ranged from 0.04% to 1.27%, while the available phosphorus (AvP) concentration ranged from 2.8 to 82.1 mg/kg. The average available micronutrients (AvCu, AvZn, AvFe, and AvMn) were 0.3, 0.5, 35.2, and 8.7 mg/kg, respectively. The variability of AvP, AvFe, and ExMn was notably high, while that of other properties was relatively low. In addition, Table 1 presents descriptive statistics for four biological indicators. The range of soil respiration (CO2) was 0.02 to 1.8, with an average of 0.5. The microbial biomass carbon (MBC) ranged from 1.1 to 32.6 milligrams of carbon per gram of dry soil. The mean metabolic quotient (qCO2) was 0.01, while the mean Cmic/Corg ratio was 4.6. The data indicated that the soil samples exhibited a positive skew, with moderate variability for MBC and Cmic/Corg, and low variability for the remaining properties.

Table 1. Descriptive statistics of some physico-chemical and biological properties of soil sample

	Mean	SD	CV	Variance	Min	Max	Skewness	Kurtosis
Physical parameters								
Silt (%)	20.41	3.43	15.95	11.78	13.22	29.17	0.36	0.02
Sand (%)	64.86	8.23	38.11	67.76	41.67	79.78	-0.55	0.17
Clay (%)	14.72	6.63	31.42	44.07	4.82	36.24	0.85	0.52
ER	51.95	20.47	81.96	419.12	13.69	95.65	0.11	-0.76
CR	85.27	6.63	31.42	44.07	63.76	95.18	-0.85	0.52
AS (%)	57.52	13.64	74.98	186.06	11.08	86.06	-0.68	0.75
DR (%)	34.87	14.80	80.23	219.08	5.92	86.15	0.41	0.52
SSI (%)	25.14	9.17	43.22	84.23	3.79	47.01	0.00	-0.66
HC (cm/h)	5.16	26.71	118.66	713.71	2.89	121.55	0.27	-0.61
BD (gr/cm3)	1.31	0.13	0.56	0.01	1.02	1.58	-0.17	-0.92
FC (%)	23.73	5.78	22.60	33.48	12.00	34.60	-0.26	-0.59
WP (%)	12.68	4.07	17.40	16.61	4.90	22.30	0.03	-0.41
AWC (%)	11.04	2.20	14.00	4.85	6.60	20.60	0.57	2.42
Chemical parameters								
pH	3.97	0.51	2.78	0.26	3.20	5.98	1.39	2.38
EC dS/m	0.11	0.08	0.70	0.00	0.04	0.73	4.22	27.38
OM %	2.87	1.36	6.26	1.87	0.27	6.53	0.54	-0.19
CaCO3 %	1.37	0.39	1.78	0.15	0.21	1.99	-0.52	-0.23
SAR	0.43	0.25	1.12	0.06	0.01	1.13	0.63	-0.08
CEC me/100g	47.67	12.68	67.80	160.87	15.10	82.90	-0.13	-0.31
Ca me/100g	2.62	5.42	32.83	29.43	0.10	32.93	3.41	12.81
Mg me/100g	1.60	2.55	14.22	6.53	0.13	14.35	2.95	8.99
Na me/100g	0.39	0.35	3.29	0.13	0.03	3.32	6.05	45.68
K me/100g	1.19	1.13	9.05	1.28	0.03	9.08	3.81	23.13
H me/100g	41.85	15.08	74.88	227.46	5.71	80.59	-0.20	-0.53
Total basic cation	5.82	7.72	40.21	59.73	0.66	40.87	2.81	8.10
Base saturation	13.20	17.18	82.21	95.32	1.74	17.95	2.45	5.71
Soil nutrient elements								
TN %	0.28	0.20	1.23	0.04	0.04	1.27	1.59	4.39
P ppm	31.18	21.08	79.26	444.48	2.86	82.12	0.54	-0.99
Cu ppm	0.35	0.28	1.98	0.08	0.10	2.08	3.62	17.32
Zn ppm	0.54	0.52	3.39	0.27	0.14	3.53	3.97	19.73
Fe ppm	35.28	26.38	160.42	696.38	2.90	163.32	1.49	4.05
Mn ppm	8.72	7.89	46.70	62.38	0.90	47.60	2.30	6.97
Biological parameters								
CO2	0.50	0.36	1.82	0.13	0.02	1.84	1.38	2.36
MBC	11.67	7.98	31.48	63.83	1.11	32.59	0.74	-0.44
qCO2	0.01	0.02	0.15	0.00	0.00	0.15	2.97	10.37
Cmic/Corg	4.60	3.29	16.58	10.860	0.21	16.79	1.39	2.39

ER: Erosion ratio, CR: Clay ratio, AS: Aggregate stability, DR: Dispersion ratio, SSI: Structure stability index, HC: Hydraulic conductivity, BD: Bulk density, FC: Field capacity, WP: Wilting point, AWC: Available water content, EC: Electrical conductivity, OM: Organic matter, SAR: Sodium adsorption ratio, CEC: Cation exchange capacity, TBC: Total basic cation, BS: Base saturation, TN: Total nitrogen, MBC: Microbial biomass cation, SD: Standard deviation, CV: Coefficient of variation

Evaluation of Soil Quality Index

In this study, a total of 35 parameters were employed to assess the quality of the soil. In order to create an appropriate SQI value for each soil sample, the BWM approach was employed to assign suitable weight values to each parameter. Among the evaluated soil indicators, in terms of physical parameters, clay was identified as the best and wilting point as the worst; in terms of chemical parameters, OM was the best and EC was the worst; in terms of biological parameters, MBC was the best and qCO2 was the worst; in terms of productivity parameters, N was the best and Cu was the worst; and in terms of erosion parameters, AS was the best and SSI was the worst. In general, the physical parameters were found to be the most favorable, while the productivity parameters were the least favorable. For all indicators, the most favorable soil quality impacts were integrated with high, low, or medium (optimal range) values, ranging between 0 and 1 for each parameter, to determine the score values.

The contribution weights of main soil indicators to SQI estimated by BWM are given in Figure 4. The highest value (0.4449) was found for hierarchy soil physical indicators, while the lowest value (0.0390) was found for fertility.

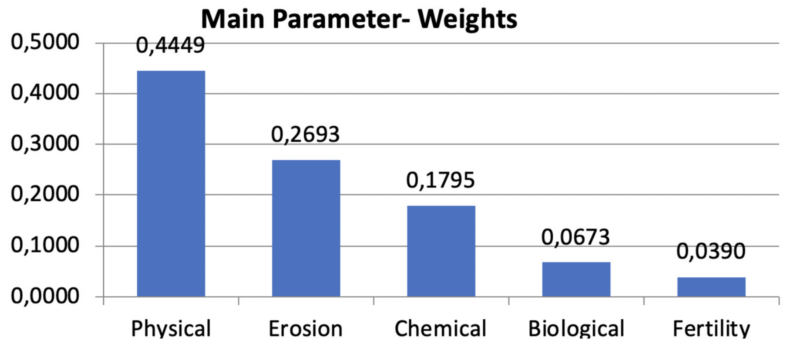

Figure 4. Weighting values of main soil indicators to SQI

Moreover, the contribution weights of sub soil indicators to SQI estimated by BWM are given in Figure 5. The highest indicator values for each sub criteria or parameter (physical, erosion, chemical, biological and fertility) were calculated as Clay (0.3146), AS (0.4560), OM (0.4406), MBC (0.5419) and TN (0.3146), respectively.

Finally, after determining the scores for each parameter value and weighting each parameter according to BWM, a weighted linear combination technique was employed to estimate SQI for each soil sample. Furthermore, the spatial distribution of SQI for each soil sample was determined through the use of deterministic methods, specifically inverse distance weighting interpolation models.

Distribution of SQI

The distribution map, created using the weights obtained from BWM and the values calculated using SSF, is presented in Figure 4. In addition, our study was compared to a research conducted by Saygın et al. (2023) and titled as "soil quality assessment based on hybrid computational approach with spatial multi-criteria analysis and geographical information system for sustainable tea cultivation" in Figure 6. It was realized that the spatial distribution of SQI values were quite similar between the SQI_BWM and SQI_AHP indices. There was also a close pattern in the both maps.

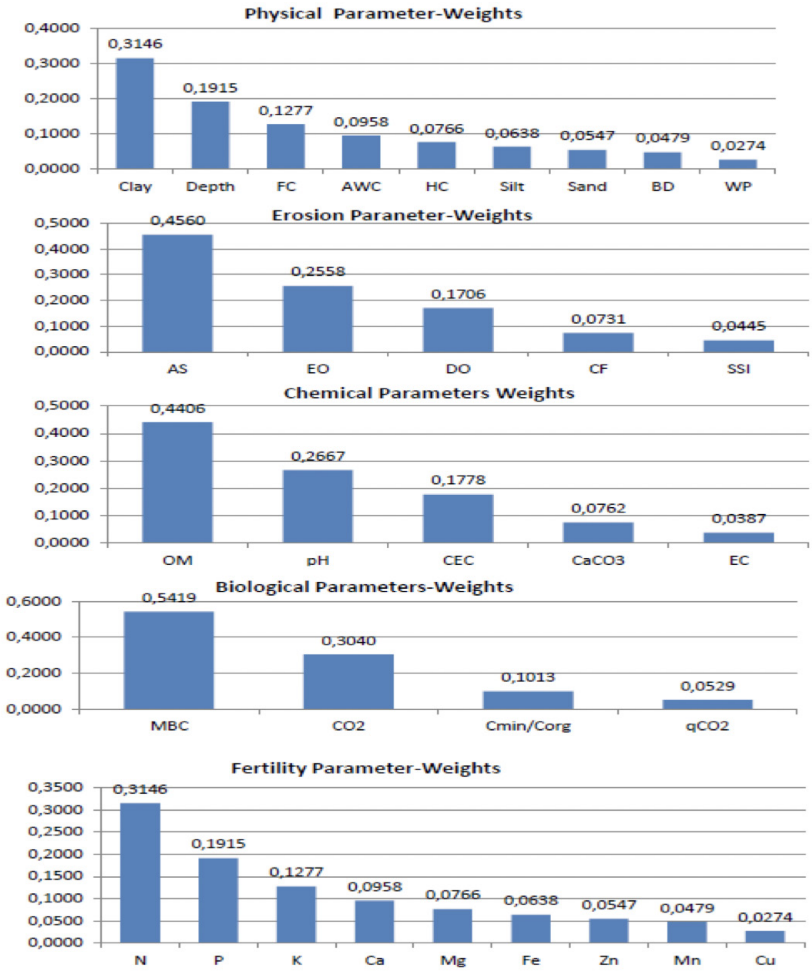

Figure 5. Weighting values of sub soil indicators to SQI

It can be observed that areas with high soil quality are located in the southern part of the study area, whereas the northern part exhibits lower soil quality. The primary reason for this is believed to be the higher slope in the northern area, which leads to increased erosion and the concomitant degradation of soil structure, fertility, and biological activity. The inclination of the land affects the physical properties of the soil, including its bulk density and aggregate stability. It has been demonstrated that steeper slopes often exhibit higher bulk density and lower aggregate stability due to the effects of compaction and erosion, which can result in the degradation of soil structure and function (Selassie et al., 2015). In the northern part of the study area, where soil quality is low, the soils have a higher sand content, which is known to increase erosion rates, bulk density, and hydraulic conductivity. This makes water retention difficult and reduces the available water content. On steeper slopes, the rate of runoff is accelerated, resulting in a reduction in the quantity of water that infiltrates into the soil. This can result in drier soils, which has a negative impact on plant growth and soil microbial activity. In contrast, gentler slopes or flat areas generally have superior water retention capacity, which is of paramount importance for the maintenance of soil health and the sustenance of vegetation (Wang et al., 2023). In this region, the water that does not adhere to soil particles and washes away also removes available nutrients.

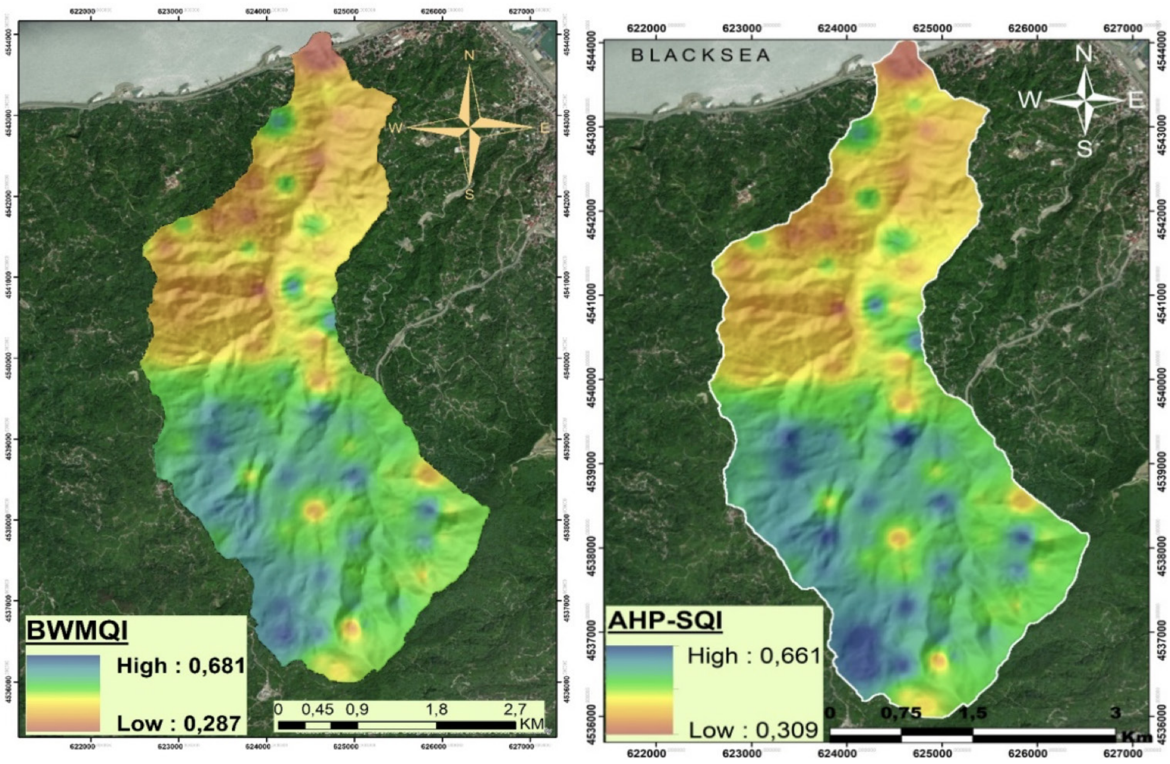

Figure 6. Distribution map of SQI based on BMW and AHP models

In the same region, it is observed that the soil organic matter content is also low. Organic matter enhances the soil's capacity to retain water. Soils with a high organic matter content have been observed to retain water more effectively, thereby facilitating the accessibility of water to plant roots (Oldfield et al., 2019). Furthermore, organic matter plays a pivotal role in the provision of essential nutrients to plants. The decomposition of organic matter releases plant nutrients, including nitrogen, phosphorus, and sulfur, which promote plant growth and productivity (Gholamhosseinian et al., 2022). The low organic matter and high sand content in the region also result in reduced aggregate stability and structural stability. Low organic matter content is indicative of a low biological activity. Soil organic matter serves as a food source for microorganisms. These microorganisms facilitate the release of plant nutrients during the decomposition process, thereby improving overall soil health. Microbial activities contribute to the improvement of soil structure and the better nourishment of plant roots (Milazzo et al., 2023). Microorganisms that rely on organic matter as a food and energy source cannot sustain their populations due to the low organic matter content and its loss from the soil.

CONCLUSION

The research resulted in a soil quality index (SQI) to evaluate soils in a micro-catchment within the humid ecosystem of Rize province in the Eastern Black Sea Region, where intensive tea cultivation is practiced. A total of 35 indicators were grouped into five criteria (physical, chemical, biological properties of the soils, fertility, and erosion) following the collection of 102 representative soil samples from the micro-catchment. The majority of soil samples exhibited high or medium quality, while the remainder displayed poor quality due to soil erosion tendencies or other issues. It is noteworthy that areas with low soil quality characteristics were distributed in the northern sections of the catchment, whereas soil quality improved towards the south part. Consequently, in areas with low soil quality, measures such as enhancing soil resistance to erosion and adding organic matter should be implemented to improve soil quality levels. Furthermore, the soil quality assessment employed in this study represents a valuable decision-making tool for tea producers and decision-makers alike, enabling them to assess the suitability of soils for tea plants. It is important to note that socio-economic and cultural factors, which assist decision-makers in making more informed decisions, should also be considered in the final decision-making process.

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Modeling and Mapping of the Spatial Distribution of the Basic Soil Properties in the Agricultural Lands Between Sariseki-Dörtyol

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ABSTRACT

Knowing the soil properties is extremely important for both the sustainability of agriculture and environmental protection. This study aims to determine the basic properties of the soils in the agricultural lands between Sarıseki-Dörtyol (Hatay) to model the distribution of these properties in the study area and create maps. For this purpose, 42 degraded soil samples were taken from 0-30 cm depth according to the random sampling method to represent the soils in the research area. Geographical coordinates of the points where soil samples were taken were recorded by using a global positioning device (GPS).

Soil samples were analyzed for pH, electrical conductivity (EC), organic matter (OM), lime, and texture. Geostatistical methods were used to determine and map the spatial distribution of soil properties. It has been determined that the distribution of the properties of the soils in the study area varies within quite different limits.

The soil samples' pH, EC, lime, and organic matter contents varied between 6.80 and 7.81, 151 and 1337 μS cm-1, 0.03% and 39.97%, 0.39% and 13.39%, respectively. The lowest coefficient of variation (VK) among the basic properties of soils is pH (3.2%), and the highest one is lime content (169.8%), followed by EC values with 65.8%. The most suitable semivariogram models were Spherical for EC, sand, and silt, Gaussian for organic matter and clay, and Exponential for pH and lime content.

Keywords: Sarıseki-Dörtyol district, soil properties, geostatistics

INTRODUCTION

Because of the benefits it provides, soils are one of our valuable natural resources, the importance of which is better understood day by day. The soil, which is necessary for the continuity of human life, must be improved to fulfill the needs of an increasing population.

That is why soil fertility comes to the fore. In addition, for the soil to be sustainable, it must be protected for the continuity of agricultural activities and human life. The sustainability of productivity and production in agricultural production is significantly related to the soil structure and properties. Therefore, it is essential to determine the soil structure and properties and to know how their spatial distribution changes.

Many physical, chemical, and biological properties of soils in the same land have a heterogeneous structure. Classical statistical methods are insufficient to determine the local variability of soils. In addition, field studies and analysis of samples taken to determine soil properties are not easy and economical. Therefore, low-cost methods are needed before assessing whether there are significant variations in the soil and for more detailed research. The production of spatial prediction maps by modeling the local variability of soil properties is one of the most common methods used to determine the soil properties of large areas at a lower cost (Turgut and Öztaş, 2012). This process can also be done easily with geostatistics.

Many studies have been carried out to determine the main properties of soils and examine their spatial distribution. For example, Bhunia et al. (2018) examined the spatial variability of soil properties using a geostatistical model in lateritic soils in the West Bengal region of India. The main chemical properties of the Arsuz plain soils were determined, and the spatial distribution maps of these properties were created in the area by Demircioğlu and Ağca (2022). Again, in a study conducted by Coşar and Ağca (2023) in the Erzin plain, the basic properties of some soils in the plain were determined, the spatial change patterns of these properties in the study area were examined, and spatial distribution maps of these properties in the study area were created using Geographical Information Systems (GIS).On the other hand, In a study in the Indian state of Madhya Pradesh, the distribution of some properties of soils, such as pH, EC, and organic matter, was determined using geostatistical methods (Sikarwar et al., 2023).

In this study, the main properties of the soils in the agricultural lands located in the Sariseki-Dörtyol district were determined, and distribution maps of these characteristics were created using geostatistical methods.

MATERIAL and METHODS

Material

The study area in the Sariseki-Dörtyol region is located between 36º40'12" - 36º49'48" north latitude and 36º09'36" - 36º15'00" east longitude. The Amanos Mountains are located to the east of the research area, and the Mediterranean Sea is located to the West. A large part of the study area is agricultural lands, while a small part is forest and heath areas. The study area is dominated by the Mediterranean climate, which is warm and rainy in winter and hot and dry in summer (Anonymous, 2004).

Methods

In this research, 42 degraded soil samples were taken from a depth of 0-30 cm according to the random sampling method to represent the study area (Figure 1). In addition, the geographical coordinates of each sampling point according to the UTM system were determined by a GPS device.

After the soil samples were carefully dried in the laboratory, they were meticulously passed through the sieve and made ready for a comprehensive analysis. Soil samples prepared for analysis were thoroughly examined for pH, electrical conductivity (EC), lime, organic matter (OM) and texture.

pH determination in the samples was measured with a pH meter in the saturation sludge, and EC was measured with an EC meter in the saturation extract (Richards, 1954). Organic matter was determined by the Walkey-Black wet-burning method (Allison, 1965), and the amount of lime was determined according to Allison and Moodie (1965). The texture analysis was carried out using the hydrometer method (Bouyoucos, 1951).

Figure 1. Geographical location of the study area and sampling points

Descriptive statistical analyses of soil properties (mean, lowest and highest values, standard deviation, coefficient of variation, skewness (skewness), kurtosis (kurtosis), etc.) have been made. The Windows-compatible SPPS 26 statistical package program was used for statistical analyses.

The Windows-compatible GS+ (version 10) geostatistics program played a crucial role in our research. It was used to model and map the distributions of soil properties, providing us with a comprehensive understanding of each parameter and a two-dimensional distribution map.

The proportional percentage of nugget semivariance (Co) to total variance (Co +C) was used as a criterion in evaluating the spatial dependencies of soil properties. If this calculated ratio is 25% or lower, the spatial dependence on the properties is considered strong; if it is between 25% and 75%, it is medium; and if it is greater than 75%, it is considered weak (Cambardella et al., 1994).

FINDINGS and DISCUSSION

Main Soil Properties

The results of the descriptive analysis of the basic properties of the soils subject to the research are presented in Table 1. The pH values of the soil samples ranged between 6.80 and 7.81, and the average pH value was determined to be 7.38. In the studies conducted by Ağca (2015) in the same region, the pH values were found to be slightly higher. This situation is most likely caused by different pH determination methods or a change in pH depending on time. The electrical conductivity (EC) values of the soils are between 151 µS cm-1 and 1337 µS cm-1, and the average EC value was found to be 439 µScm-1.

The lime content of the soils in the study area was between 0.03% and 39.97%, and the average was determined as 5.79, the organic matter content varied between 0.39% and 13.39%, and the average was determined as 3.92 %. As can be seen from the results, the lime content of soils varies within very wide limits. This situation is most likely caused by the formation of alluvial deposits from different parent materials in a large part of the study area. Because most of the areas where soils are formed are formations representing the quaternary period, basalts, rubble covers, and alluvions that spread over a wide area are formed. There are also limestones and dolomitic limestones, conglomerates, serpentinized ultra-basic rock fragments, and serpentine arenites in this area (Koç and Değer, 1991).

Table 1. Descriptive statistical analysis results of the soil properties

Parameter	pH	EC (µS cm-1)	Lime (%)	Organic matter (%)	Partical size distribution (%)		
					Sand	Silt	Clay
Minimum	6.80	151	0.03	0.39	10.4	16.1	7.7
Maximum	7.81	1337	39.97	13.49	73.6	59.1	48.5
Mean	7.38	439.3	5.79	3.92	40.8	32.3	26.9
SD	0.24	289.2	9.83	2.38	15.3	10.6	8.7
CV %	3.2	65.8	169.8	60.7	37.5	32.8	32.3
Skewness	-0.45	1.78	2.43	1.81	0.16	0.68	0.21

Our research has revealed significant variations in the organic matter content of soils, ranging from 0.39% to 13.49%, with an average of 3.92%. This variation is of utmost importance, particularly in the areas where samples 9, 24, 28, and 36 were taken, which are untreated forested areas under the cover of vegetation. The breakdown of organic matter is significantly slower under natural vegetation cover than in processed areas, a finding that underscores the importance of our research in understanding soil composition and organic matter content.

Sand contents varied from 10.4% to 73.6%, silt contents from 16.1% to 59.1%, and clay contents from 7.7% to 48.5% (Table 1). Ağca (2015) also found in his study that the organic matter, sand, silt, and clay distributions of the soils of the same region were similar to those in this study. The small differences between them have been caused by the soils' heterogeneity.

Among the basic properties of soils, our research has provided reliable and robust findings. The lowest VK value is in pH (3.2%), the highest is in lime content (169.8%), and pH is followed by EC values of 65.8%. These results are consistent with the study conducted by Mohamed et al. (2021) and add to the body of knowledge in this field. Abdennour et al. (2020) also found the lowest VK value in pH values, but the VK of EC values was found to be lower than the VK values of other parameters. This shows that the pH values in the research area are quite homogeneous, and the lime contents are heterogeneously distributed. Skewness values also confirm this situation. The smaller the skewness values of a feature, the more homogeneous the distribution of this feature in the research area. The lime content with the highest VK value also has the highest heterogeneity value. According to Zhou et al. (2011), if the coefficient of variation is less than 10%, the variability level is low; if it is between 10 and 100%, the variability level is medium; and if it is greater than 100%, the variability level is high. Our findings, based on rigorous research methods, provide a comprehensive understanding of soil properties, with pH values being quite homogeneous and lime contents being distributed quite heterogeneously. The homogeneity levels of other parameters were moderate, contributing to a nuanced understanding of soil properties.

Modeling of the Spatial Distribution of Soil Properties

In the modeling of the spatial distribution of soil properties, due to the low skewness values, no conversion was made to the data sets of pH, sand, silt and clay contents before geostatistical modeling.Due to high skewness values; after applying logarithmic transformation to lime and EC values and square root transformation to organic matter contents, data sets were used in modeling. The semivariogram parameters ofsoilpropertiesare given in Table 2.The most suitable semivariogram model in the study area soils is Guassian for pH, organic matter and clay contents; Spherical for EC, sand and silt contents; Exponential also for lime contents (Table 2). Variousresearchershave determined the most suitable semivariogram models for the basic soil properties in their studies.For example, Mondal et al. (2021) in their study; the most suitable model for EC values was Spherical, Sharma et al. (2020) determined that the most suitable model for pH values of is Exponential.Again, in a study conducted by Li et al. (2011) in China, the most suitable model for soil organic matter is Spherical, In the studies conducted by Reza et al. (2017) and Ahmad et al. (2018), it was determined that the most suitable model for the sand content of soils is Exponential. On the other hand, according to Sunetal. (2003), in the modeling of spatial variability of the soil properties, most suitable semivariogram models are Spherical, Exponential and Gaussian (Gurel, 2020).

Table 2. Semivariogram parameters of soil properties

Parameter	Model	Ao (m)	Nugget (C0)	Sill (C0+C)	(C0)/ (C0+C)*100	r2
pH	Gaussian	2930	0.015	0.087	17.2	0.839
EC	Spherical	2620	0.151	0.303	49.8	0.489
Lime	Exponential	1210	2.555	5.111	49.99	0.580
Organic matter	Gaussian	14590	0.229	1.539	14.87	0.822
Sand	Spherical	4360	113.3	226.7	49.977	0.681
Silt	Spherical	4040	59.9	119.9	49.958	0.410
Clay	Gaussian	10890	43.8	298.5	14.673	0.831

In geostatistics, the A0 (range) value indicates the maximum distance at which the spatial dependence persists for any variable (Isaaks and Srivastava, 1989). After this distance, there is no spatial dependency between the points. The soil properties in the research area ranged from 1210 m (Lime) to 14590 m (organic matter). This situation shows that the spatial dependence on soil properties varies within vast limits. Many researchers have also found different results in this regard. For example, Reza et al. (2017) reported that the A0 value for clay content of soils was 2352 m, Doğan et al. (2020) in their study in the Arsuz plain, the A0 value for pH was 700 m, and Sharma et al. (2020) determined the A0 value for EC values as 1599 m. Although the silt content in this study anic matter) Dety was 4040 m (Table 2), and in the study conducted by Ahmad et al. (2018), the A0 value of the silt contents was found to be quite high (31470 m). The breadth of different research areas may have most likely caused this difference.

According to Nugget/Sill ratios of soil properties (Cambardella et al., 1994), spatial dependence is strong in terms of pH, organic matter, and clay contents; it is moderate for lime, EC, silt, and sand contents.

Mapping of soil properties

The ordinary Kriging interpolation method was used to map the basic properties of soils. The spatial distribution maps created using this method are presented in Figure 2. When the pH values of the study area soils are examined on the distribution map, it is observed that the distribution is mainly between 7.21 and 7.57 values. The highest pH values were found in the study area's middle parts, and pH values decreased as one moved toward the north. It has been observed that the distribution of EC values of the soils is mainly between 302 – 240 µS cm-1 and increases in a northwestern direction and reaches the highest values. The lowest EC values (0 - 240 µS cm-1) were determined to be in the middle parts of the study area (Figure 2).

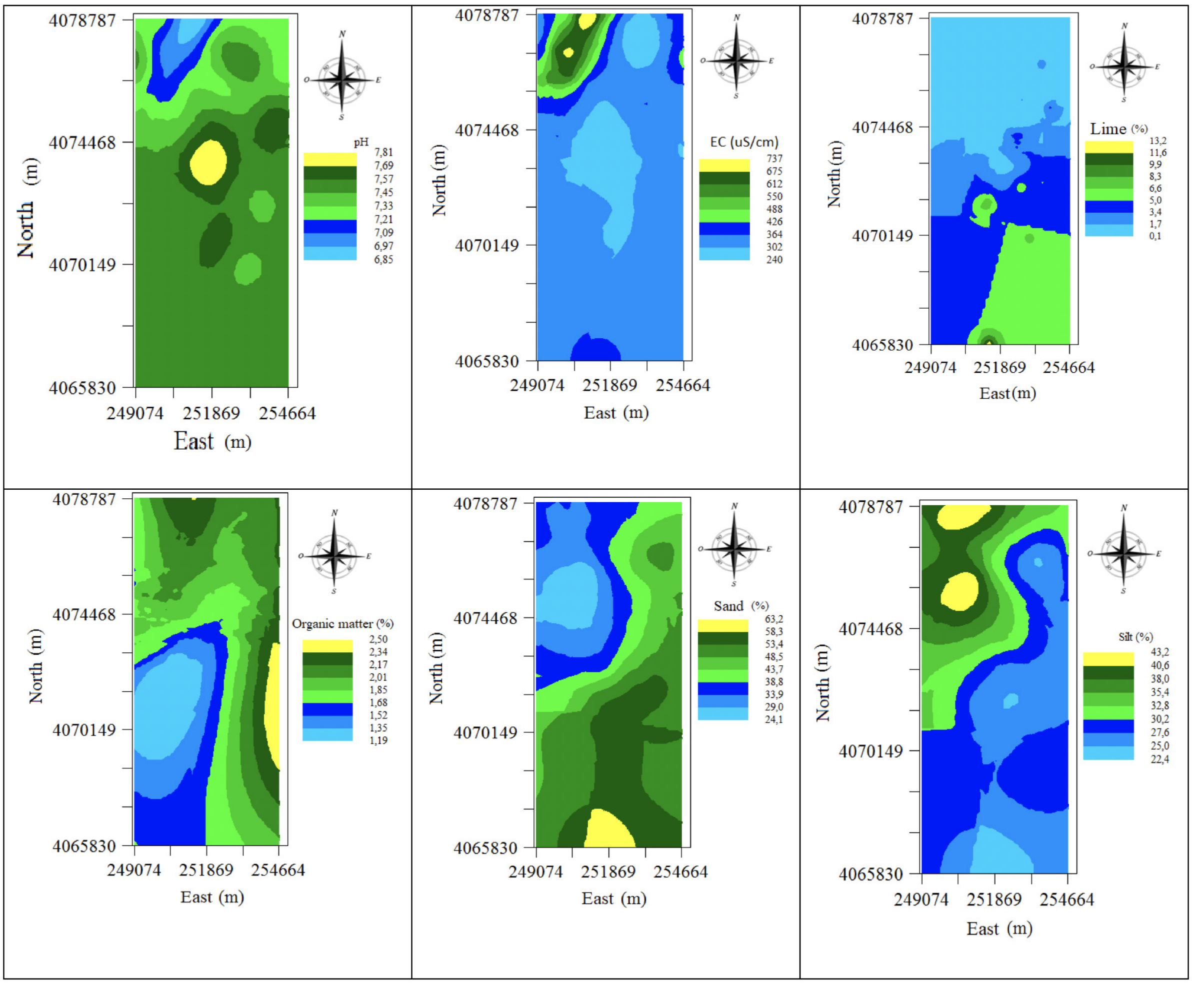

Figure 2. Spatial distribution maps of soil properties in the study area

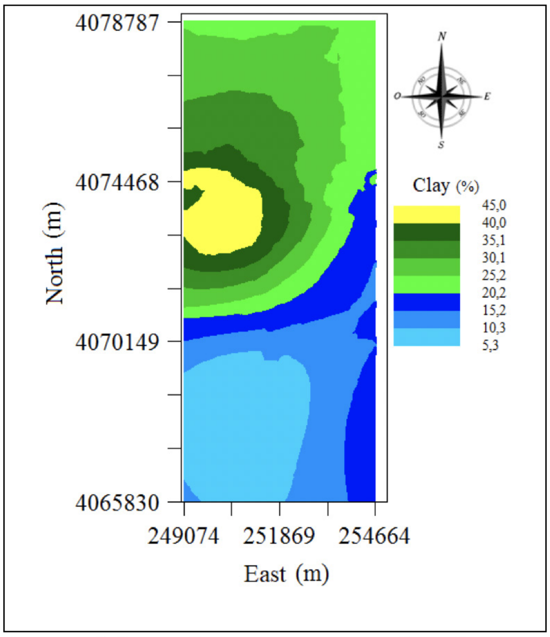

Figure 2 (Continued). Spatial distribution maps of soil properties in the study area

When the distribution of the lime content of the soils in the study area is examined, it is seen that the lowest values are in the northern part, and the highest values are in the southeastern part. The organic matter content of the soils is high in the eastern parts of the area and decreases towards the western and northern parts. The high organic matter content in the eastern part is due to the forested areas in this region. The lowest organic matter content in the area is also seen in the western parts (Figure 2).

It was determined that the sand content distribution of the study area's soils was concentrated mainly in the south; these values decreased towards the northwest, and the lowest values were in the northwestern part. It is observed that the silt values of the soils are high in the northwestern parts and low in the southeastern parts of the area. When the clay content distribution of the soils is examined, it is seen that it is mainly low in the southern sections of the study area and high in the northern sections (Figure 2).

RESULT

This study aims to model the spatial distribution of soil properties, an important criterion in determining the productivity potential, and create maps of the spatial distribution of each property in the area. There is not enough research on the properties of soils in the Sariseki-Dörtyol region. It has been determined that the distribution of soil properties in the study area varies within quite different limits.

It has been determined that the parameter distributed most homogeneously in the area is pH, and the lime content is the most heterogeneously distributed. The lime content of the soils has varied within very wide limits. The majority of the soils have a medium (loam) texture. Of the total 42 soil samples, 34 have medium structures (loam, sandy loam, sandy clay loam, and clay loam), while only 8 have fine (clay) textures. For this reason, these soils' nutrient content and air and water permeability are quite good.

The reaction of soils varies from neutral to moderately alkaline. The contents of organic matter have varied within very wide limits. However, it has been determined that it is generally high in forested areas to the east and low in flat areas. Farm manure should be applied to areas with low organic matter content to increase the organic matter and nitrogen content. Again, it is more appropriate to apply acidic fertilizers such as ammonium sulfate or urea as nitrogenous fertilizer to soils with high lime content.

The results of this study will form the basis for more detailed studies to be conducted in the region and will significantly contribute to our knowledge about regional soils.

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Predicting Soil Moisture Constants Using Some Soil Properties of Cultivated Fields

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ABSTRACT

In this study, the relationships between soil moisture constants such as; field capacity (FC), permanent wilting point (PWP), available water content (AWC) and some soil physicochemical properties were determined in 90 surface soil samples (0-20 cm) taken from cultivated fields around Samsun, Turkey. After analyzing clay, silt, sand contents, soil reaction (pH), electrical conductivity (EC), organic matter (OM) content, bulk density (BD) of the soil samples, multiple linear regression models using stepwise analyses in SPSS program were done between soil moisture constants and some soil properties. The FC values varied between 13.80% and 46.00% with a mean of 30.75%, the PWP values varied between 6.00% and 35.10% with a mean of 17.42% and the AWC values varied between 5.50% and 22.47% with a mean of 13.33%. While all moisture constants (FC, PWP, AWC) had significant positive correlations with clay, pH, EC and OM contents, they gave significant negative correlations with BD and sand contents. To predict moisture constants, the regression models were produced by stepwise analyses. When using the second order of variables in the regression models, the values of standard error of estimation reduced. The highest R2 values of the first order and second order linear regression equations were estimated as 0.915** and 0.952** for FC, 0.816**and 0.850** for PWP. The best model for AWC was found with first order and second order linear regression equations (R2:0.837** and 0.839** respectively). The values of FC and PWP can be predicted much better when using the linear regression equation including second order variables. It was determined that BD, OM, clay, sand and silt contents are the most effective soil properties on predicting of soil moisture constants in cultivated fields.

Keywords: Field capacity, wilting point, soil properties, linear models

INTRODUCTION

In sustainable agriculture, the continuity of soil and water quality depends on the knowledge of the relationships among soil properties. In the study subjects such as soil hydrological properties and plant relations, soil moisture characteristics should be determined (Rawls, 1982; Puckett et al., 1985). Direct measurement of soil moisture constants requires laboratory works and it is time consuming (Rawls, 1982). Pedotransfer functions are multiple regressions developed for the determination of these moisture constants using soil properties that have a significant effect on soil moisture constants (Salchow, 1996). The parameters used in pedotransfer functions generally include soil properties such as texture, organic matter content and bulk density (Gülser and Candemir, 2008; Candemir and Gülser, 2012; Gülser and Candemir, 2014; Gülser 2016; Gülser and Ekberli, 2019). Field capacity (CF) is defined as the percentage moisture content retained in the soil at a pressure of 0.33 bar after the movement of water removed by free drainage after precipitation or irrigation applications is completed. Permanent wilting point (PWP) is the amount of moisture retained by the soil at a pressure of 15 bar (Hillel, 1982). The objective of this study is to determine themultiple linear regression models between soil moisture constants and some soil properties using first order and second order variables.

MATERIAL and METHODS

In this study, 90 surface soil samples were taken from 0-20 cm depth of arable soils around Samsun, Türkiye. Soil physical and chemical analyses were determined in air-dried soil samples in the laboratory. Clay, silt and sand contents were determined according to the hydrometer method (Demiralay, 1993), organic matter (OM) contents were determined according to the "Walkley-Black" method (Kacar, 1994). pH and electrical conductivity values (EC 25°C) were measured in 1:1 soil:water suspension, and bulk density (DB) values were determined according to Tüzüner (1990). Field capacity (FC) and permanent wilting point (PWP) moisture constants were determined by keeping soil samples saturated for 24 hours on ceramic plates of 1 and 15 bars, respectively, under 0.3 and 15 bar pressure until their moisture content reached equilibrium (Klute, 1986). Moisture constants were taken as dependent variables and stepwise regression models with measured soil properties were created using the SPSS 17.0 computer program.

RESULTS

Descriptive statistical information on some physical and chemical properties of the soils used in the study is given in Table 1. The soil samples are generally showed normal distribution for particle size. According to the EC values, 82,2% of soil samples is non saline, 14,4% is very slightly saline and 3,4% is slightly saline. Distribution of soil reaction (pH) level of samples is classified as 2,8% very strongly acid, 14,2% slightly acid, 17,1%neutral, 28,6 slightly alkaline and 37,3% moderately alkaline. Organic matter contents of samples are 14,4% very low, 47,7% low, 27,7% moderate and 10,0% high (Soil Survey Staff, 1993).

Table 1. Some physical and chemical properties of the research soils (n=90)

	Minimum	Maximum	Mean	Std. Deviation	CV, %	Skewness	Kurtosis
Clay, %	9,99	68,73	34,03	16,58	48,71	0,40	-0,81
Silt, %	3,05	48,74	27,25	9,00	33,02	0,11	-0,37
Sand, %	6,84	81,71	38,72	19,24	49,70	0,28	-1,00
OM, %	0,20	3,87	1,87	0,75	40,09	0,30	-0,19
pH (1:1)	4,85	8,22	7,39	0,79	10,66	-1,53	1,70
EC, dS/m	0,11	2,65	0,65	0,45	69,37	1,91	5,23
BD, g/cm3	1,06	1,60	1,40	0,15	10,73	-0,56	-0,79
FC, %	13,80	46,00	30,75	8,68	28,24	-0,34	-0,91
PWP, %	6,00	35,10	17,42	6,88	39,49	0,44	-0,32
AWC, %	5,50	22,47	13,33	3,94	29,58	0,52	-0,43

Descriptive statistical results for FC, PWP and AWC are given in Table 1. Field capacity of the soil samples used in this study varied between 13,80% and 46,00% with a mean of 30,75%. Permanent wilting point of the soil samples varied between 6,00% and 35,10% with a mean of 17,42. Available water content values varied between 5,50% and 22,47% with a mean of 13,33%. All soil moisture constants showed significant positive correlations with pH, EC, clay and organic matter contents, while they had significant negative correlations with bulk density and sand content. In most studies, it was reported that water holding capacity of soils increase with increasing clay, organic matter, and decrease with increasing bulk density and sand content (Gülser, 2004a; Gülser, 2006; Gülser et al., 2010; Candemir and Gülser, 2011; Gülser and Candemir, 2014; 2015, Gülser et al., 2015; Demir and Gülser, 2021).

DISCUSSION

To estimate FC, PWP and AWC values of soil samples, linear regression models were obtained running the stepwise analyses in the SPSS programme with using some soil physical and chemical properties (Table 2). When using the second order of variables in the regression models, the values of R2 increased and RMSE reduced. The highest R2 values of the first order and second order linear regression equations were estimated as 0.952** for FC (Figure 1), 0.850** for PWP (Figure 2) and 0.839** for AWC (Figure 3). RMSE values reduced from 2,514% to 2,018% for FC and from 2,934% to 2,668% for PWP when including second order values of clay and sand contents in the multiple linear regression models. The best model for AWC according to R2 and RMSE values is estimated also using 2nd order BD variable in the model. But, improvement in the 1st order model is not much as well as FC and PWP. Gülser (2004b), predicted field capacity and wilting point moisture constants of farmland soils by pedotransfer equations taking into account the relationships with some physical and chemical properties of the soils. He also reported that FC and PWP constants gave statistically very significant relationships with clay, sand, total porosity, organic matter and electrical conductivity values. He concluded that using physical and chemical properties of the soils together in the equations increased the significance level of the FC and PWP values.

Table 2. Moisture constants models and significant levels

Moisture Constants Models	R^2	RMSE,%
FC-1st order = -37,566 + 0,611*C + 0,289*Si + 25,639*BD + 2,038*OM	0,915**	2,514
FC-2nd order = -10,934 + 0,808*C - 0,005*C2 – 0,002*S2 +16,102*BD + 1,523*OM	0,952**	2,018
PWP-1st order = -66,330 + 0,455*C - 0,167*S + 49,684*BD +2,817*OM	0,816**	2,934
PWP-2nd order = -71,033 + 1,046*C - 0,006*C2 + 40,888*BD + 2,608*OM	0,850**	2,668
AWC-1st order = 43,371 + 0,128*Si - 22,899*BD - 0,799*OM	0,837**	1,581
AWC-2nd order = 58,416+ 0,136*Si - 46,563*BD + 8,917*BD2 - 0,700*OM	0,839**	1,571

** statistically significant at 0,01 level

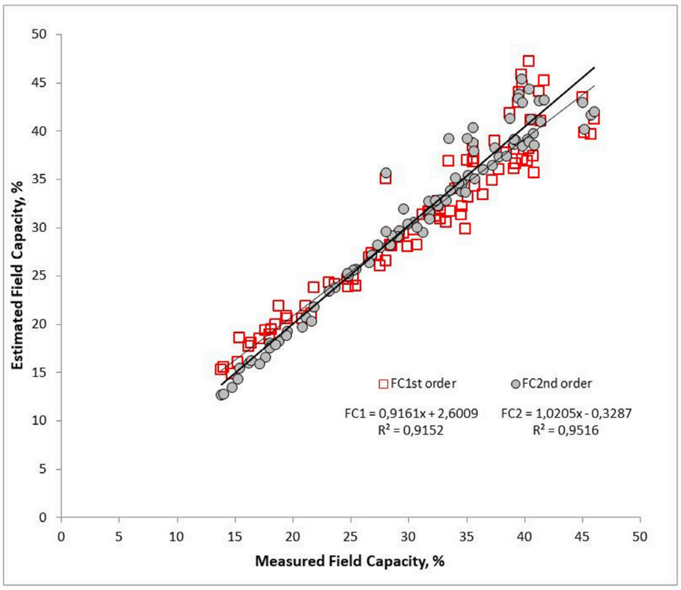

Figure 1. Relationships between measured field capacity (FC) and FC values calculated from multiple regression equations

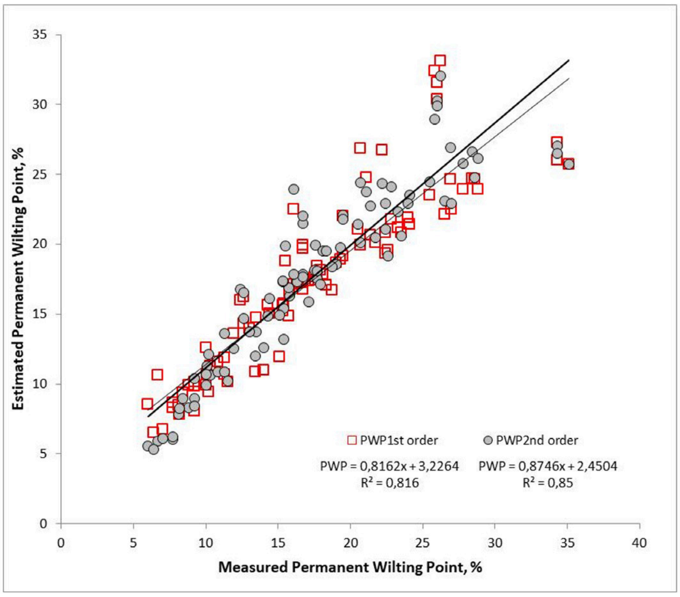

Figure 2. Relationships between measured permanent wilting point (PWP) and PWP values calculated from multiple regression equations

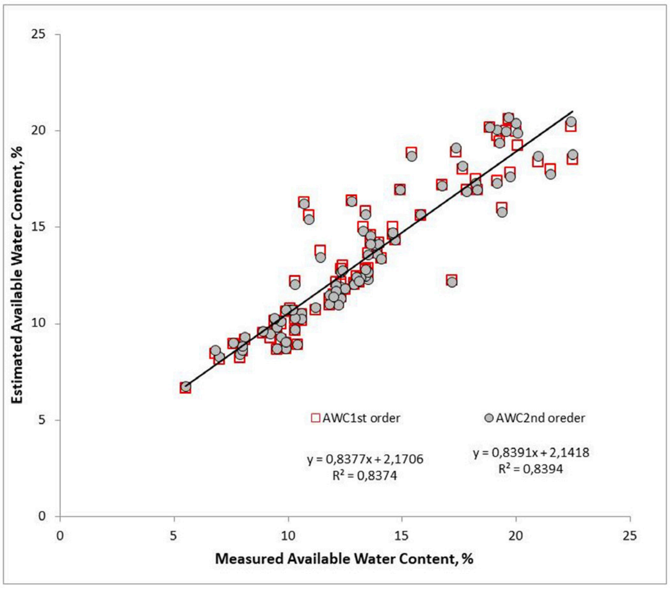

Figure 3. Relationships between measured available water content (AWC) and AWC values calculated from multiple regression equations

It seems possible to calculate the FC and PWP constants of soils using multiple regression equations created by some soil physical and chemical properties. In the obtained pedotransfer equations, the physical properties of the soils play a more effective role in determining the moisture constants than the chemical properties. As a conclusion, the values of FC and PWP can be predicted much better when using the linear regression equation including second order variables. It was determined that BD, OM, clay, sand and silt contents are the most effective soil properties on predicting of soil moisture constants in cultivated fields. The validity of the models should be examined with more soil sample data.

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Investigation of the Effect of Polystyrene on Soil Organic Carbon (Corg) in Agricultural Soils of Gaziantep Province

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ABSTRACT

Plastic pollution threatens ecosystems due to its increasing use. In recent years, it has been observed that microplastics have increased in agricultural soils. Knowing the effects of microplastics on soil properties is very important for soil management. This study examines the impact of polystyrene on soil organic carbon (Corg) in Gaziantep's agricultural soils. Soil samples were collected 0-20 cm from 20 pistachio (Pistacia vera L.) and olive (Olea europaea L.) orchards in Nizip, dried in air and sieved with a 2 mm. The soil samples were weighed as 100 gr and divided into four groups: The control samples (CT) received no treatment, whereas the second group (PS) received 24% polystyrene (w/w), the third group (LO) received 10% leonardite (w/w), and the fourth group (PL) received the same amounts of both polystyrene and leonardite. After 30 days, pH varied between 7.47-8.26 in CT, 7.53-7.93 in PS, 7.19-7.86 in LO, and 7.63-7.96 in PL. The electrical conductivity (EC) was in the range of 207-1061 μS/cm in CT, 338-1233 μS/cm in PS, 500-1417 μS/cm in LO, 443-1422 μS/cm in PL. The carbonate (IC) was found between 10.13-91.25% in CT, 10.20-60.00% in PS, 11.00-57.00% in LO, and 11.00-57.30% in PL. Corg were detected in the range of 0.40-1.57% in CT, 0.54-1.63% in PS, 0.52-1.65% in LO, and 0.5 5-1.43% in PL. The sequence of dominance was CT>PL>PS>LO for pH, PL>LO>PS>CT for EC, CT>PS>LO>PL for IC, and LO>PL>PS>CT for SOM. Statistical analysis showed that EC values increased and IC decreased in the PS, LO and PL ($P<0.05$) according to CT. Results indicate that polystyrene and leonardite treatments did not significantly affect SOM. Protecting alkaline soils from plastic pollution is crucial for soil quality and fertility maintenance.

Keywords: Gaziantep, leonardite, orchard soils, polystyrene, soil organic matter

INTRODUCTIONS

Polystyrene [(C8H8)n] is commonly utilized in creating food packaging (such as meat trays and egg cups), disposable cups and plates, thermal insulation materials, various carrying containers, plastic lab tools and equipment, and toys (SAPEA, 2019), and is recognized as one of the plastics that decompose at a notably slow rate despite being derived from petroleum-based carbon polymers (Bodor et al., 2024)thanks to their versatility and durability. However, their extensive use, coupled with inadequate waste disposal, has resulted in plastic becoming ubiquitous in every environmental compartment, posing potential risks to the economy, human health and the environment. Additionally, under natural conditions, plastic waste breaks down into microplastics (MPs<5 mm. Nevertheless, in the environment, polystyrene gradually breaks down into smaller macroplastics (>5 mm), microplastics (1 μm-5 mm), and nanoplastics (0.1-1 μm) over time due to physical and chemical influences, including sunlight exposure, heat, and fluctuations in temperature (Akça et al., 2024).

Furthermore, leonardite, a type of oxidized lignite, is abundant in organic and humic compounds and plays a vital role in enhancing soil organic matter, which is essential for sustainable agricultural practices by promoting soil fertility (Sönmez & Öktüren Asri, 2024). Moreover, it has the potential to mitigate the adverse impacts of polystyrene pollution by improving soil structure and nutrient retention (Awet et al., 2018).

Recent research has unveiled compelling evidence that the presence of polystyrene at micro or nano scales, like other plastic types, alters the physicochemical characteristics of soils. For instance, Rassaei (2024) demonstrated that elevated concentrations of polystyrene microplastics (PS-MP) alone lead to a reduction in soil pH, soil organic matter, essential plant nutrients like phosphorus and potassium, while simultaneously increasing EC. Furthermore, it has been evidenced that these alterations induced by polystyrene within the physicochemical composition of soils significantly influence the microbial flora responsible for sustaining nutrient cycles in soils, thereby affecting enzyme activities within those soils (Awet et al., 2018).

Although research regarding the presence of plastics, particularly in agricultural regions, has surged in Turkey, these investigations primarily focus on the detection and abundance of various plastics in soils (Akça et al., 2022, 2024; Gündoğdu et al., 2022). However, in a study conducted by Demir et al. (2024), the impacts of polystyrene nanoparticles (PS-NP) on urease and catalase enzyme activities in soils were examined for the first time in Turkey. In this regard, the objective of this study was to assess whether the applications of polystyrene and leonardite (LO) have meaningful positive or negative impacts on SOM, pH, EC, and IC, which are crucial for soil and crop productivity in agricultural settings, particularly in pistachio orchards practicing dry farming, and to evaluate whether any effects of polystyrene on these soil properties can be mitigated through the combined application of polystyrene and leonardite.

MATERIALS AND METHODS

In this study, soil samples were collected from 20 pistachio and olive orchards in Nizip. Samples were taken from the topsoil (0-20 cm) using the zigzag method and dried at Gaziantep University Soil Ecology Laboratory. Soil samples were sieved with a 2 mm sieve. The samples were divided into four groups of 100 grams each. The first group received no treatment (CT). 24% (w/w) polystyrene microplastic (CAS No. 9003-53-6, d=1.05g/cm3, Carl Roth, Karlsruhe, Germany) added in the second group (PS). The third group was supplemented with 10% (w/w) leonardite (Fosil Power, Çanakkale, Türkiye) for agricultural use (LO). The leonardite pH and EC values and soil organic matter (SOM) contents is respectively 5.84±0.12, 1,420±109 (µS/cm) and 44.35±3.86%. In the fourth group samples, both polystyrene microplastic and leonardite were added in the same proportions as in the second and third groups (PL). All samples were moistened to their relative humidity and incubated for 60 days.

After incubation, pH and EC (µS/cm) were measured in a 1:2.5 soil-water mixture using a multimeter (Consort C5020, Turnhout, Belgium) (Richards, 1954). Carbonate contents (IC) were measured with a Scheibler calcimeter (Eijelkamp M1.08.53.D, Holland) following methods for soils with low MnO2 and organic carbon content (Allison and Moodie, 1965). Corg was assessed using a titrimetric method suitable for high carbonate soils (Walkley and Black, 1934; Nelson and Sommers, 1996). A one-way ANOVA test (p=0.05) was conducted to assess group differences, using IBM SPSS (Version 27, SPSS Inc., Chicago, IL, USA) for specific comparisons (Turkey). Descriptive statistics were generated with R Studio (Posit Software, PBC) (RCoreTeam, 2022). Minitab 19 (Version 19, Minitab Ltd., Coventry, UK) was utilized for graphical representation. Each analysis was conducted three times to ensure accuracy in the statistical results.

RESULTS

Our results showed that orchards soils generally have slightly alkaline reaction, non-saline, calcareous, clayey loam soils with low SOM content according to their average values (Table 1). According to the 95% confidence interval (CI), soil pH was found to vary between 7.70 and 7.86 (mean 7.78±0.19). EC were found to be 371.19 and 569.15 µS/cm (average 470.17±225.85 µS/cm). The average value of IC, which varied between 52.82% and 70.55%, was 61.69±20.23%. Corg were found to be between 0.76% and 0.99% (average 0.88±0.27%). Clay, silt and sand contents were found to vary between 31.87%

and 40.27% (average 36.07±9.58%), 25.13% and 29.09% (average 27.11±4.53%) and 32.60% and 41.04% (average 36.82±9.63%), respectively.

The order of soil pH values was soil CN>PL>PS>LO (Figure 1a). According to CT, soil pH was found to decrease by 0.83%, 1.33% and 0.35% in PS, LO and PL, respectively ($p>0.05$). The order of EC was found to be PL>LO>PS>CN (Figure 1b). According to CT, EC increased by 48.7%, 87.71% and 87.54% in PS, LO and PL, respectively ($p<0.001$). The order of IC was CN>PS>LO>PL (Figure 1c). This finding showed that according to CT, IC decreased by 22.63%, 26.30% and 30.53% in PS, LO and PL, respectively ($p>0.001$). The order of Corg was PL>LO>PS>CN (Figure 1d). Corg of soils increased by 13.09%, 16.43% and 13.73% in PS, LO and PL compared to CT ($p>0.05$).

Table 1. Descriptive statistics results of selected general properties of soils

	pH	EC (µS/cm)	IC (%)	Corg (%)	Clay (%)	Silt (%)	Sand (%)
Min	7.47	207.05	10.13	0.40	21.66	18.29	20.42
CI (-0,95%)	7.70	371.19	52.82	0.76	31.87	25.13	32.60
Mean	7.78	470.17	61.69	0.88	36.07	27.11	36.82
Median	7.77	432.00	64.22	0.82	35.51	27.46	36.16
CI (0,95%)	7.86	569.15	70.55	0.99	40.27	29.09	41.04
Max	8.26	1061.00	91.25	1.57	61.30	33.78	52.92
StD	0.19	225.85	20.23	0.27	9.58	4.53	9.63
Kurt.	0.95	1.49	1.36	1.15	0.95	-0.94	-0.80
Skew.	0.93	1.22	-1.14	0.70	0.66	-0.15	0.25
CV	2.42	48.03	32.80	30.34	26.57	16.70	26.16

DISCUSSION

The predominantly slightly alkaline, non-saline, highly calcareous, and low organic carbon content observed in the soils of pistachio and olive orchards in this investigation can be linked, as highlighted in prior research, to the region's arid climatic conditions and limited precipitation ranging from 400 to 600 mm (Tunç et al., 2022; MGM, 2024), as well as agricultural soils derived from geological substrates such as limestone and gypsum

(Tunç & Özkan, 2010; Demir et al., 2023), in addition to conventional agricultural practices including intensive and prolonged crop harvesting, stubble burning, or the removal of stubble for various purposes (Tunç & Gül, 2014; Çelik et al., 2017).

The present study revealed that the application of polystyrene and leonardite did not yield a significant impact on soil pH levels. This finding aligns with previous studies, which documented either an increase (Zhao et al., 2021; Rassaei, 2024a) or a decrease (Dong et al., 2021) in soil pH following polystyrene treatment. Such variations are likely attributable to the differing electrostatic and hydrophobic influences of polystyrene (Zhang et al., 2024)"ISSN":"24701343","abstract":"Microplastics (MPs on soils with divergent physical and chemical characteristics (Rassaei, 2024a). In contrast to the findings of this research, another study indicated that leonardite treatment contributed to a reduction in soil pH, which was linked to the organic acids generated during the decomposition process and the heightened CO2 emissions (Ateş and Namlı, 2021).

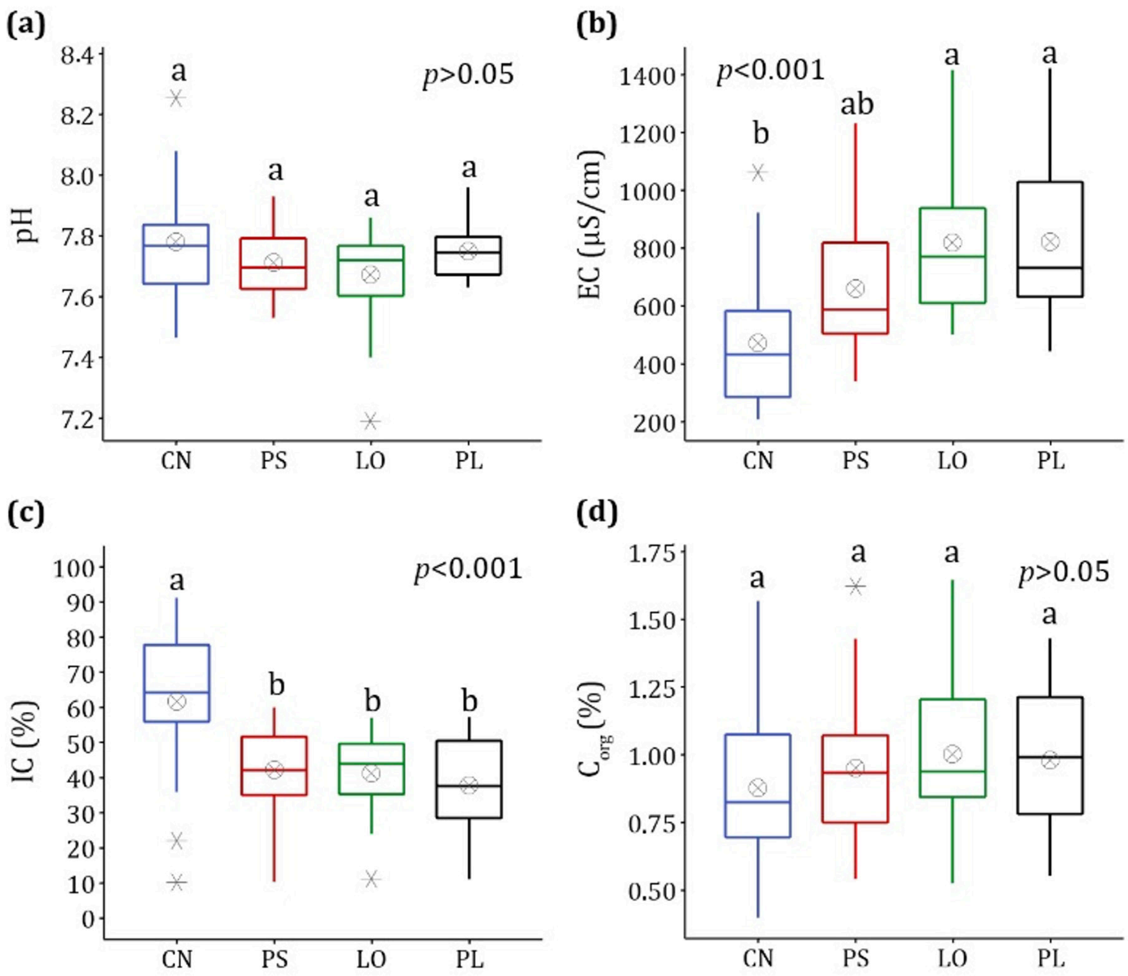

Figure 1. Changes in soil pH, EC (µS/cm), IC (%), and Corg (%)

The treatment of both polystyrene and leonardite resulted in a marked increase in EC and a substantial reduction in IC content within the soils. Prior studies reporting similar outcomes suggested that the elevation in EC was associated with the hydrophobic nature of polystyrene (Rassaei, 2024a, 2024b)N'-disuccinic acid (EDDS. The rise in EC is also related to the abundant organic matter and residue present in soils following leonardite treatment (Sönmez and Öktüren Asri, 2024). The findings from this study indicate that both polystyrene (Rassaei, 2024b)and leonardite treatment (Sağlam et al., 2012)enhance the solubility of soil carbonates. The reasons for the significant decrease in IC in both polystyrene and leonardite applications compared to the control are due to the fact that polystyrene induces precipitation with carbonate (Mahadevan et al., 2021) and the interaction of carboxyl groups of organic matter fractions such as humic acid of leonardite with cations such as Ca^{+2} in carbonates (Hoch et al., 2000).

A global assessment of the impact of microplastics on soil respiration revealed that polystyrene induced a 21% increase in Corg levels, alongside a 25% rise in CO_2 emissions attributed to alterations in microbial communities (Zhao et al., 2024). It was observed that smaller polystyrene microplastics (0.1 μm) adversely affected the dynamics of Corg due to stress inflicted on the microflora (Li et al., 2024). Conversely, leonardite was found to augment Corg contents in soils, enhancing soil quality and productivity owing to its organic matter content (Sönmez & Öktüren Asri, 2024). Within this study, no substantial differences were identified among varied applications, a result likely linked to the region's inherently low Corg levels.

CONCLUSION

The assessment of physical, chemical, and biological metrics of soil serves as an indicator of soil vitality. The application of polystyrene and leonardite exhibits varying influences on the chemical characteristics of soils. There was no notable alteration in soil pH, while EC in soils increased and IC decreased. Furthermore, it was ascertained that the applications of microplastic polystyrene and leonardite did not significantly impact the carbon cycles within soils. This investigation provides foundational insights for future inquiries aimed at comprehending the prolonged implications of polystyrene on soil organic matter. The findings of this study partially bridge the knowledge gap regarding the impacts of polystyrene and other microplastics on soil health.

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Estimation of Potassium Fixation Capacity of a Clay Soil

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ABSTRACT

Sorption mechanism of cations in soil is one of the most important processes, influences the mobility of nutrients in vadose zone.The Langmuir and Freundlich isotherms are generally used for the adsorption of cations by the soil colloidal fractions. The objective of this study was to determine the potassium fixation capacity of a clay soil by Langmuir, Freundlich isotherms and using polynomial and power functions. The soil samples were shaken with 1:5 soil: KCl solutions (2, 4, 8, 16, 24, 32, 40, 60, 80 and 120 meq/L) for 24 hours. The amount of exch. K was determined with NH4Acc. Extraction method using AAS. While experimental K fixation capacity values varied between 0.79 and 25.69 me/100g, estimated K fixation values varied between 0.77 and 18.79 me/100g by Langmuir isotherm, 1.09 and 29.07 me/100 g by Freundlich isotherm, 0.92 and 27.42 me/100 g by power function, 1.75 and 24.04 me/100 g by polynomial function. Validation of the models used for estimation of soil K fixation capacity was analyzed with RMSE. While the highest RMSE was obtained with Langmuir isotherm (2.625 meq/100g), the lowest RMSE was determined as 0.947 meq/100 g by polynomial function. The precision of the estimation of K fixation capacity were ordered as polynomial function > power function > Freundlich isotherm > Langmuir isotherm. The K fixation capacities of clay soils can be estimated using polynomial functions precisely instead of using the isotherms.

Keywords: Potassium, fixation, Langmuir, Freundlich, polynomial, power function

INTRODUCTION

The sorption of cations by soil colloidal fractions is a critical process influencing the mobility and availability of essential nutrients in the soil's vadose zone. Potassium, a vital macronutrient for plant growth, plays a crucial role in various physiological processes, including enzyme activation, osmoregulation, and photosynthesis (Sparks & Huang, 1985). The availability of potassium in soils is largely determined by the soil's ability to fix or release this nutrient, particularly in clay-rich soils characterized by high cation exchange capacity.

Potassium fixation in soils occurs when K^+ ions are trapped in the interlayer spaces of clay minerals such as illite and vermiculite, rendering them less available for plant uptake (Barrow, 2012). The extent of this fixation is influenced by factors such as soil mineralogy, K^+ concentration, and environmental conditions, making it a dynamic process (Sparks, 2000). To quantify potassium fixation, various mathematical models have been utilized, including the Langmuir and Freundlich isotherms, which describe the adsorption behavior of cations on soil particles (Langmuir, 1918; Freundlich, 1906; Demirkaya and Gülser, 2018a). These models provide valuable insights into the binding intensity and capacity of soils for potassium.

However, the precision of these isotherms can vary significantly depending on soil type, particularly in soils with complex mineralogical compositions (McLean & Watson, 1985). Consequently, alternative methods such as polynomial and power functions have been proposed to offer more precise estimations of potassium fixation capacity. These functions, which accommodate non-linear relationships and complex interactions, may better capture the behavior of potassium fixation in diverse soil conditions (Bohn et al., 2001).

In recent years, it is known that mathematical functions are frequently used in estimating the properties of soil related to its physical, chemical and biological properties (Gülser and Demir 2016; Ekberli et al. 2017; Ekberli et al. 2021; Ekberli and Gülser, 2022). The objective of this study is to evaluate the potassium fixation capacity of a clay soil using the Langmuir and Freundlich isotherms, as well as polynomial and power functions. The precision of these methods were analyzed by comparing experimental data with model estimates using RMSE term. This research seeks to identify the most accurate approach for predicting potassium fixation capacity in clay soils.

MATERIAL AND METHOD

In this study, a clay soil sample (0-20 cm) was used. The soil sample was taken from the experimental field of Agricultural Faculty in Ondokuz Mayıs University, Samsun. Soil chemical and physical properties were determined as follows; particle size distribution by hydrometer method (Demiralay, 1993), soil pH, 1:1 (w:v) soil:water suspension by pH meter, electrical conductivity (EC25ºC) in the same suspension by EC meter, lime content by Scheibler Calcimeter method, organic matter content by Walkley-Black method and cation exchange capacity (CEC), exchangeable cations by ammonia acetate extraction (Kacar, 1994).

KCl was used as the K carrier to prepare the fixation solution. The soil samples were shaken with 1:5 soil: KCl solutions including 2, 4, 8, 16, 24, 32, 40, 60, 80 and 120 me K/L for 24 hours and filtered. The amount of potassium in the soil solutions was determined using the Atomic Adsorption Spectrophotometer.

The potassium adsorption of soils is showed by the following isotherm equations.

$$S=bkC/(1+kC) \text{ or } \frac{1}{S}=\frac{1}{b}+\frac{1}{bkC} \qquad \text{Langmuir (1918);}$$

$$S=K_fC^{(1/n)} \text{ or } \lg S=\lg K_f+\frac{1}{n}\lg C \qquad \text{Freundlich (1930);}$$

Where, S is amount of potassium adsorbed on the soil (me/100g), b (me/100g), k and (1/n) are the coefficients expressing the potassium adsorption capacity of soil, C (me/L) is the concentration of potassium in the equilibrium soil solution, Kf is the equilibrium coefficient which expresses the potassium holding capacity of the soil. The amount of K adsorbed by soil particles (S) was estimated subtracting the K concentrations in equilibrium solutions (C) from the initial K concentrations of the solutions used in the experiments.

Potassium fixation capacity of soils was also determined using polynomial and power functions according to the experimental data. Relationships (R2 values) between experimental and estimated values of K fixation and RMSE values were estimated by Excel programme.

RESULTS

The soil physical and chemical properties are given in Table 1. These results can be summarized as; the clay soil sample is none saline, neutral in pH, medium in organic matter content (Soil Survey Staff, 1993).

Table 1. Some physical and chemical properties of the soil

Clay, %	62.74	Organic Matter, %	2.42
Silt, %	25.13	CEC, me/100g	53.0
Sand, %	12.13	Na, me/100g	0.42
pH (1:1)	6.78	K, me/100g	0.72
EC, dS/m	0.60	Ca, me/100g	22.03
CaCO3, %	3.40	Mg, me/100g	19.74

Langmuir and Freundlich isotherms obtained using the linear relationship between S and C adsorption data for different textural soils are given in Figure 1. The coefficients of the both isotherm (b, k, Kf and 1/n) are given in Table 2.

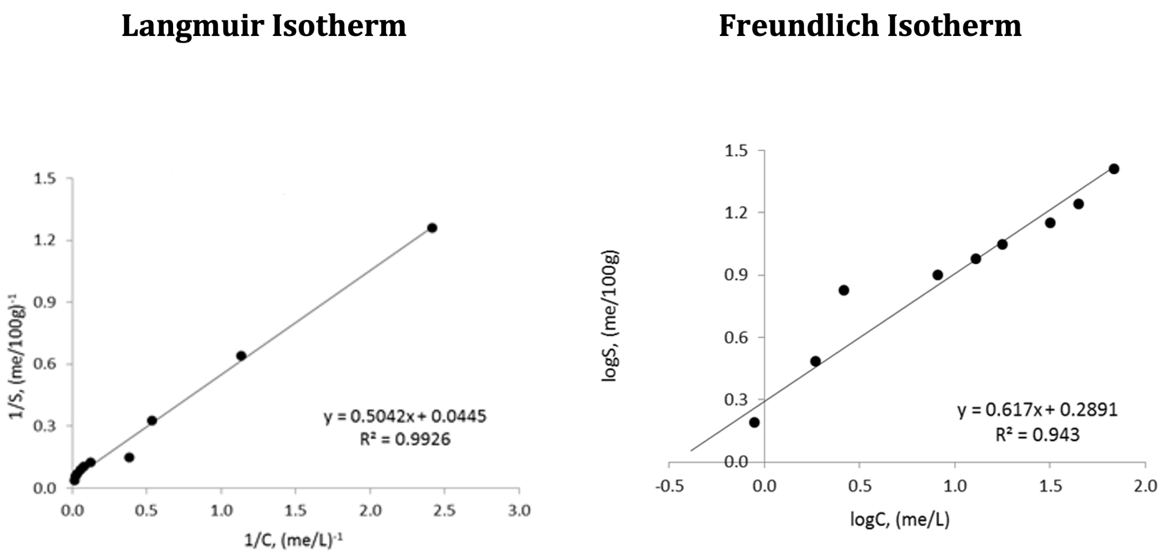

Figure 1. Langmuir and Freudlich Isotherms in clay soil

Table 2. The coefficient and determination values of Langmuir and Freundlich Isotherms

	Langmuir Isotherm			Freudlich Isotherm	
	b	k	MBC*	Kf	1/n
Clay Soil	22.47	0.09	2.02	1.92	0.62

*MBC: Maximum Buffering Capacity

According to the experimental K fixation data, polynomial and power functions were derived in excel programme (Figure 2). Experimental and estimated K fixation values by clay soil are given in Table 3 and Figure 3. While experimental K fixation capacity values varied between 0.79 and 25.69 me/100g, estimated K fixation values varied between 0.77 and 18.79 me/100g by Langmuir isotherm, 1.09 and 29.07 me/100 g by Freundlich isotherm, 0.92 and 27.42 me/100 g by power function, 1.75 and 24.04 me/100 g by polynomial function.

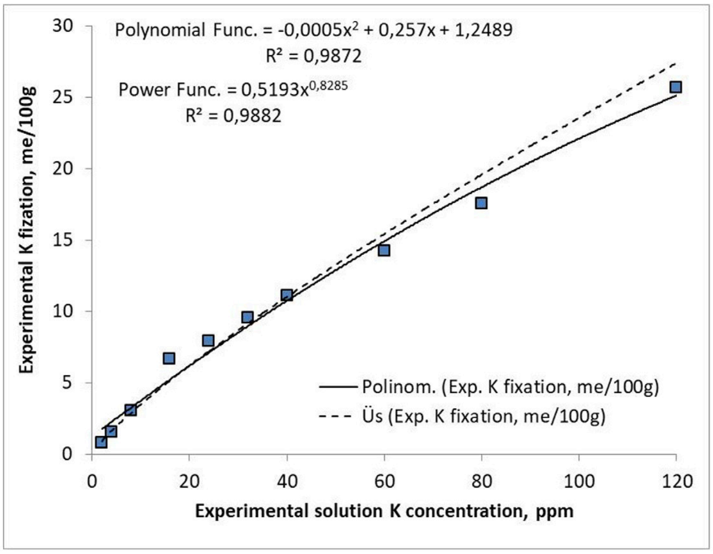

Figure 2. Relationship between measured K fixation and experimental solution K concentration

Table 3. Experimental and estimated K fixation values (meq/100 g) of clay soil

Sol. K meq/L	Exp. K fix.	Langmuir	Freundlich	Polinomial Func.	Power Func.
2	0,79	0,77	1,09	1,75	0,92
4	1,56	1,58	1,77	2,24	1,64
8	3,07	3,09	2,86	3,22	2,91
16	6,70	4,09	3,54	5,12	5,16
24	7,95	9,13	7,35	6,96	7,23
32	9,55	11,66	9,92	8,74	9,17
40	11,11	13,37	12,19	10,45	11,03
60	14,22	16,11	17,64	14,45	15,44
80	17,54	17,49	22,14	18,05	19,59
120	25,69	18,79	29,07	24,05	27,42

DISCUSSION

Marković et al. (2014) reported that the first and one of the most important conditions for selecting any isotherm model is that there should be a good fit between the experimental data and the isotherm function.Al-Ghouti and Da'ana (2020) indicated three conditions for an isotherm model to be thermodynamically feasible. I) the isotherm model should be linear when the concentration is zero, ii) there should be a finite capacity at maximum concentration and iii) the gradient of the function should be positive for all concentrations. Ehiomegue et al. (2021) reported that the conventional method of determining the best fit isotherm model involves linearizing the model and then checking for fit using linear regression. Demirkaya and Gülser (2018b) compared of experimental data with obtained from adsorption isotherms; Freundlich (R2 0.97) equation explained K fixation behavior better than the Langmuir (R2 0.95) equation as evidenced by higher coefficient of determination. They concluded that K adsorption behavior of clay soil was explained very well using Freundlich isotherm. In this study The coefficient of determination (R2) and RMSE values indicated that the better fits of equilibrium K adsorption data were determined for clay soil ordered as polynomial function > power function > Freundlich isotherm > Langmuir isotherm (Table 4). The precision of the estimation of K fixation capacity was higher when using polynomial function than using the adsorption isotherms.

Table 4. The coefficient of determination (R2) values and RMSE of K fixation models

K Fixation models	R2	RMSE, meq/100g
Langmuir Isotherm	0,876**	2,625
Freundlich Isotherm	0,971**	2,369
Polinomial Function	0,987**	0,947
Power Function	0,991**	1,085

As a conclusion, the K fixation capacities of clay soils can be estimated using polynomial functions precisely instead of using Langmuir or Freundlich isotherms. The validity of the polynomial function should be examined with more experimental data for more soil samples having different textural classes.

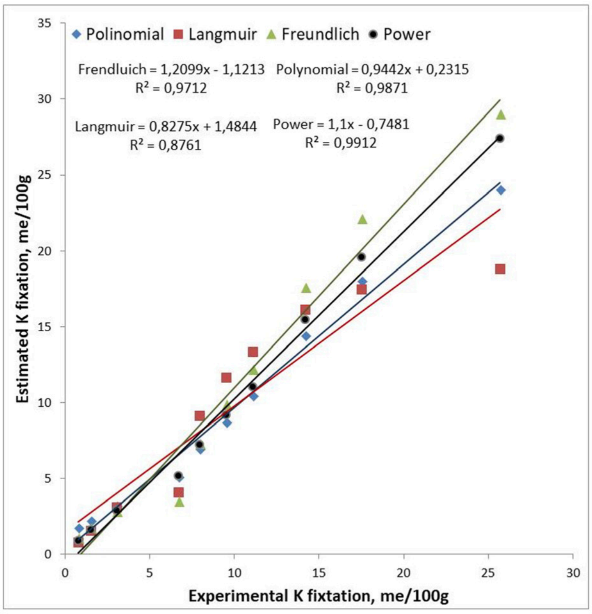

Figure 3. The relationships between measured K fixation data and estimated K fixation values

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Comparative Effects of Standard and Indigenous Azotobacter Chroococcum Strains on Wheat Yield

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ABSTRACT

This study investigates the effects of two strains of Azotobacter chroococcum—Beijerink 1901 (DSMZ 2286) and indigenous RK49—on the yield and nitrogen (N) concentrations of spring wheat (Triticum aestivum) under both greenhouse and field conditions. The Beijerink 1901 strain, a widely recognized non-indigenous strain, was compared to the RK49 strain, isolated from the rhizosphere of pasture grasses in Northern Anatolia, Turkey. Results from greenhouse experiments showed that seeds inoculated with the Beijerink 1901 strain exhibited a significant increase in grain yield by 97% and straw yield by 33% compared to the control group. Nitrogen concentration in grains also improved, reaching up to 2.11%. Similarly, the indigenous RK49 strain demonstrated remarkable performance in field conditions, leading to an 84% increase in grain yield and a 92% increase in straw yield. Moreover, RK49 inoculation significantly enhanced nitrogen concentration in both grain and straw, making it a promising candidate for sustainable agricultural practices. The findings suggest that while the Beijerink 1901 strain remains highly effective, the indigenous RK49 strain is equally, if not more, potent in improving wheat yield and nitrogen content, particularly under field conditions. This study underscores the potential of indigenous bacterial strains like RK49 in enhancing crop productivity and promoting sustainable agriculture in the region. The utilization of locally adapted strains could offer a viable alternative to chemical fertilizers, contributing to ecological restoration and sustainable agricultural practices.

Keywords: Azotobacter chroococcum, wheat yield, nitrogen fixation, indigenous strains, biofertilizer

INTRODUCTION

Sustainable agriculture hinges on the use of renewable inputs that can maximize ecological benefits while minimizing environmental damage (Vance, 1997). In agroecological restoration, a critical challenge is the reduction of nitrogen (N) loss through volatilization, erosion, leaching, and crop removal (Badejo, 1998). While chemical fertilizers have traditionally been used to combat N loss, their extensive application has led to environmental pollution, ecological degradation, and increased production costs (Ghost and Bhat, 1998; Gerber et al., 2005; Mitsch and Day, 2006). To address these issues, biofertilizers—products containing living microorganisms capable of converting essential nutrients into forms accessible to plants—are being increasingly recognized as a sustainable alternative (Döbereiner, 1997; Vessey, 2003).

Azotobacter chroococcum, a free-living nitrogen-fixing bacterium commonly found in soils, has garnered significant attention due to its ability to enhance soil fertility and plant growth. Studies have shown that inoculation with A. chroococcum can lead to substantial increases in the yield and N concentration of crops like wheat (Triticum aestivum) (De Freitas, 2000; Kumar et al., 2001a). This bacterium not only fixes atmospheric nitrogen but also produces growth-promoting substances such as gibberellins, indole-3-acetic acid, and cytokinins, which contribute to improved plant growth (Azcon and Barea, 1976; Barea and Brown, 1974). Furthermore, A. chroococcum can solubilize phosphate, produce siderophores, and secrete antifungal compounds, making it a versatile tool in sustainable agriculture (Kumar and Narula, 1999; Suneja et al., 1994; Lakshminarayana, 1993).

The effectiveness of A. chroococcum strains can vary significantly depending on whether they are indigenous or non-indigenous to the region. Indigenous strains, which are adapted to local environmental conditions, often exhibit superior performance compared to non-indigenous strains due to their higher competitiveness and better adaptability (Bhattarai and Hess, 1993; Salantur et al., 2005). This study focuses on comparing the standard A. chroococcum Beijerink 1901 strain, widely used in agricultural practices, with the indigenous RK49 strain, isolated from Northern Anatolia, Turkey. By evaluating these strains' effects on wheat yield and nitrogen content under greenhouse and field conditions, this research aims to identify effective biofertilization strategies that promote sustainable agriculture in the region.

MATERIAL AND METHOD

Soil Sampling

To evaluate the effects of Azotobacter chroococcum Beijerink 1901 and the indigenous RK49 strain on wheat yield and nitrogen content, soil samples were collected from various locations in Northern Anatolia, Turkey. For the RK49 strain, soil samples were taken specifically from the rhizosphere of pasture grasses in the region. The soil was collected at a depth of approximately 20 cm using a sterile soil corer, which was sterilized with 95% ethanol before each use. Approximately 500 g of soil was collected from each location and transported to the Soil Microbiology Laboratory at Ondokuz Mayıs University, where the samples were stored at 4°C until further analysis (Hartemink, 2005; Ramos and Martínez-Casasnovas, 2006). These samples were used for the isolation and cultivation of both the RK49 strain and the standard Beijerink 1901 strain, with additional soil samples analyzed for their physico-chemical properties, including pH, organic matter content, and nutrient levels.

Isolation and Culturing of Azotobacter Chroococcum Strains

Both A. chroococcum Beijerink 1901 and RK49 strains were isolated and cultured using nitrogen-free Ashby medium, which included glucose, mannitol, CaCl2, MgSO4, Na2MoO4, K2HPO4, KH2PO4, FeSO4, CaCO3, and agar (Clark, 1965). For isolation, 10 g of soil from each sample was shaken with 90 mL of sterile distilled water, followed by serial dilution. One milliliter of each dilution was plated onto triplicate agar plates containing N-free Ashby medium and incubated at 30°C for 72 hours. Colonies showing characteristic pigmentation were selected for further purification. The RK49 strain, indigenous to the region, and the standard Beijerink 1901 strain (DSMZ 2286) were identified through morphological, biochemical, and cultural characteristics (De Freitas, 2000; Reis et al., 1994). The purified strains were maintained in nutrient broth with 15% glycerol at -80°C for subsequent experiments.

Seed Inoculation

Pure cultures of the A. chroococcum Beijerink 1901 and RK49 strains were grown in N-free Ashby agar at 30°C. After 72 hours of aerobic incubation on a rotating shaker, bacterial suspensions were prepared with a final concentration of 10^9 CFU mL^-1. Wheat seeds (Triticum aestivum META 2002) were inoculated by soaking them in the respective bacterial suspensions for 30 minutes under sterile conditions before sowing (Kumar et al., 2001b; Narula et al., 2000). The inoculated seeds were then used in both greenhouse and field experiments.

Greenhouse and Field Experiments

To assess the impact of A. chroococcum Beijerink 1901 and RK49 strains on wheat growth, separate experiments were conducted under greenhouse and field conditions.

In the greenhouse experiment, 5 L pots were filled with soil collected from a fallow field in Merzifon, Northern Anatolia. The experiment included three treatments: wheat seeds inoculated with the Beijerink 1901 strain, seeds inoculated with the RK49 strain, and a control group without inoculation. Each treatment was replicated three times and arranged in a completely randomized design. The pots were irrigated regularly to maintain appropriate moisture levels, and plants were harvested 83 days after sowing (Meshram and Shende, 1982; Salantur et al., 2005).

For the field experiment, 1 m × 1 m plots were established in the same region, with the same three treatments as in the greenhouse experiment. The plots were arranged in a randomized complete block design, with three replications per treatment. The physico-chemical properties of the soil used in the field were consistent with those in the greenhouse experiment. Wheat seeds were sown at a density of 500 seeds/m^2. The plots were irrigated at key growth stages, and the plants were harvested 106 days after sowing (Pandey et al., 1998; Haahtela et al., 1988).

Harvest and Study Parameters

At the conclusion of both experiments, grain and straw yield, as well as nitrogen concentration in grains and straw, were measured. The study parameters were assessed using established protocols, as described by Ryan et al. (2001). All measurements were performed in triplicate, and the data were statistically analyzed using SPSS 11.0 software. Differences between treatments were evaluated using the LSD (Least Significant Difference) test at a 5% significance level.

RESULTS AND DISCUSSION

Grain and Straw Yield

The results from both the greenhouse and field experiments demonstrated that the inoculation of wheat seeds with Azotobacter chroococcum strains Beijerink 1901 and RK49 significantly increased grain and straw yield compared to the control treatment. In the greenhouse experiment, the Beijerink 1901 strain led to the highest increase in grain yield, with an observed increase of 97% compared to the control. Similarly, the RK49 strain also showed a substantial enhancement in grain yield, though slightly lower than Beijerink 1901, with an increase of 84%. These results indicate the strong positive effect of A. chroococcum inoculation on wheat productivity under controlled conditions.

In the field experiment, the indigenous RK49 strain outperformed the Beijerink 1901 strain in terms of straw yield. The RK49 strain resulted in a 92% increase in straw yield, compared to the 33% increase observed with the Beijerink 1901 strain. The better performance of the RK49 strain under field conditions could be attributed to its adaptation to local environmental conditions, which likely provided it with a competitive advantage in the rhizosphere. These findings align with previous studies suggesting that indigenous strains are often more effective in their native environments (Bhattarai and Hess, 1993; Salantur et al., 2005).

Nitrogen Concentration in Grains and Straw

The nitrogen (N) concentration in both grains and straw was significantly influenced by the inoculation with A. chroococcum strains. In the greenhouse experiment, the Beijerink 1901 strain produced the highest N concentration in grains, reaching 2.11%, while the RK49 strain led to a slightly lower but still substantial N concentration of 1.95%. The higher N concentration associated with the Beijerink 1901 strain could be attributed to its well-documented nitrogen-fixing efficiency and growth-promoting capabilities (De Freitas, 2000; Vessey, 2003).

In the field experiment, the RK49 strain excelled in enhancing the N concentration in both grains and straw. The RK49 inoculation resulted in a 10% higher N concentration in grains compared to the control, highlighting its potential as an effective biofertilizer in field conditions. The improved N concentration in the field experiment with RK49 could be due to its superior adaptation to the local soil and climatic conditions, which may have facilitated better nitrogen fixation and uptake by the plants (Kumar et al., 2001a; Narula et al., 2000).

Comparative Performance of Beijerink 1901 and RK49 Strains

The comparative analysis of the Beijerink 1901 and RK49 strains reveals distinct advantages for each strain under different conditions. The Beijerink 1901 strain demonstrated superior performance in the controlled greenhouse environment, likely due to its robust nitrogen-fixing capabilities and consistent growth-promoting effects across various studies (Azcon and Barea, 1976; Barea and Brown, 1974). On the other hand, the RK49 strain, being indigenous to the region, showed remarkable efficacy in the field, particularly in enhancing straw yield and nitrogen concentration. This suggests that RK49's adaptation to the local environment makes it a more suitable candidate for field applications in Northern Anatolia.

These results underscore the importance of selecting appropriate bacterial strains based on environmental context. While non-indigenous strains like Beijerink 1901 can provide substantial benefits under controlled conditions, indigenous strains such as RK49 offer a more tailored and potentially more effective solution for field applications. This highlights the potential for using indigenous bacterial strains in sustainable agriculture to optimize crop yield and nutrient content while minimizing environmental impact (Döbereiner, 1997; Suneja et al., 1994).

CONCLUSION

The study confirms that both A. chroococcum Beijerink 1901 and RK49 strains can significantly enhance wheat yield and nitrogen content. However, the choice between these strains should be informed by the specific environmental conditions of the cultivation area. The RK49 strain, in particular, shows great promise for use in biofertilizer applications in Northern Anatolia, where its adaptation to local conditions enables it to perform optimally. Future research should focus on further exploring the application of indigenous strains like RK49 in different ecological zones to support sustainable agricultural practices.

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Osmoprotectants Mitigate Adverse Effects of Boron Toxicity in Wheat Root Parameters

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ABSTRACT

Plants encounter diverse environmental fluctuations, including drought, salinity, and imbalances in nutrient levels, both excessive and deficient. Boron (B), a micronutrient crucial for the growth and well-being of all agricultural crops, operates within a narrow threshold between deficiency and toxicity. Osmoprotectants, a class of organic compounds characterized by their low molecular weight and non-toxic nature, play a significant role in augmenting plant tolerance mechanisms. Prominent examples of osmoprotectants include Proline (Pro), Glycinebetaine (GB), and Trehalose (Tre). However, the defense mechanisms employed by osmoprotectants in plants under conditions of B toxicity remain poorly understood. The objective of this study was to investigate the effects of Pro, GB at a concentration of 1mM, and Tre at a concentration of 10μM on wheat (Triticum aestivum L.) subjected to B toxicity conditions (1mM). It was observed that under toxic conditions, plant growth parameters, and the antioxidant capacity decreased. Additionally, there was a significant increase in the level of Malondialdehyde, indicating oxidative damage, in the presence of B toxicity. In contrast, the application of exogenous osmoprotectants to wheat plants experiencing B toxicity resulted in the alleviation of stress symptoms observed in the mentioned root parameters. Moreover, the study found that all osmoprotectant treatments enhanced the tolerance of wheat plants when exposed to stressful conditions.

Keywords: Osmoprotectant, boron, Triticum aestivum, antioxidant capacity

INTRODUCTION

Abiotic stress is a major factor that limits plant growth and productivity around the world. Among these stresses, boron (B) toxicity is particularly challenging, especially in areas where soil contains high levels of B. While boron is an essential micronutrient for plant growth, the range between what is beneficial and what is harmful is very narrow. Excess boron causes oxidative stress, disrupts physiological processes, and stunts plant growth, ultimately reducing crop yields (García-Sánchez et al., 2020). Wheat (Triticum aestivum L.) is especially sensitive to B toxicity, making it essential to find effective ways to manage this issue. Plants have developed several defense mechanisms to deal with abiotic stress, one of which involves the accumulation of osmoprotectants (OP) such as proline, glycinebetaine, and trehalose. These compounds help stabilize cellular structures, maintain osmotic balance, and reduce oxidative damage caused by stress (Zulfiqar et al., 2020).

Proline, a common osmoprotectant, serves multiple functions: it acts as an osmolyte to help plants manage water stress, scavenges reactive oxygen species (ROS), and stabilizes proteins and cell membranes (Shafi et al., 2019). Glycinebetaine plays a crucial role in maintaining the integrity of cell membranes and protecting the plant's photosynthetic machinery, which helps it tolerate stress (Zulfiqar et al., 2020). Trehalose has recently attracted attention for its ability to stabilize proteins and membranes, as well as its role in stress-responsive signaling pathways (Morgutti et al., 2019).

This study focuses on the effectiveness of applying these osmoprotectants—proline, glycinebetaine, and trehalose—externally to reduce the harmful effects of boron toxicity in wheat. Specifically, it looks at how these compounds affect growth, oxidative damage, electrolyte leakage, and the activity of antioxidant enzymes. By exploring how these osmoprotectants work, this research aims to provide insights into sustainable strategies for managing boron toxicity in wheat, ultimately helping to improve crop productivity in stressful conditions.

MATERIALS AND METHODS

Plant Material and Growth Conditions

Wheat seeds were surface sterilized and sown in plastic pots for hydroponic growth under controlled environmental conditions. The temperature was maintained at 25 ± 2°C, with humidity levels between 60-70%, and a light/dark photoperiod of 16 hours of light and 8 hours of darkness. Throughout the experiment, the plants were supplied with Hoagland's nutrient solution to ensure proper nutrition.

Experimental Design and Treatments

This study aimed to investigate the effects of exogenous application of Proline (Pro) and Glycinebetaine (GB) at a concentration of 1 mM each, and Trehalose (Tre) at 10 μM, on wheat (Triticum aestivum L.) grown under boron (B) toxicity conditions. Boron toxicity was induced by applying 1 mM of B to the hydroponic system. The experiment was designed to evaluate the potential mitigating effects of these osmoprotectants on the wheat's ability to tolerate B toxicity.

Measurements

Key growth parameters, such as shoot and root length, as well as fresh and dry weight, were recorded to assess plant growth under the different treatments. In addition, malondialdehyde (MDA) content was measured to evaluate lipid peroxidation, an indicator of oxidative stress. Electrolyte leakage was also assessed to determine cell membrane stability under B toxicity. Furthermore, the activities of key antioxidant enzymes, catalase (CAT) and peroxidase (POX), were analyzed using spectrophotometric assays, following the methods outlined by Elbasan et al. (2024), to gain insights into the plant's oxidative stress response.

RESULTS AND DISCUSSION

Results

The findings of this study highlight the crucial role of osmoprotectants (OP) — namely proline, glycine betaine, and trehalose — in reducing the harmful effects of boron (B) toxicity on wheat growth. Under boron toxicity, wheat plants experienced significant reductions in key growth metrics: root length decreased by 44%, fresh weight by 35%, and dry weight by 41%. However, the application of exogenous OPs substantially alleviated these negative effects in all treatment groups.

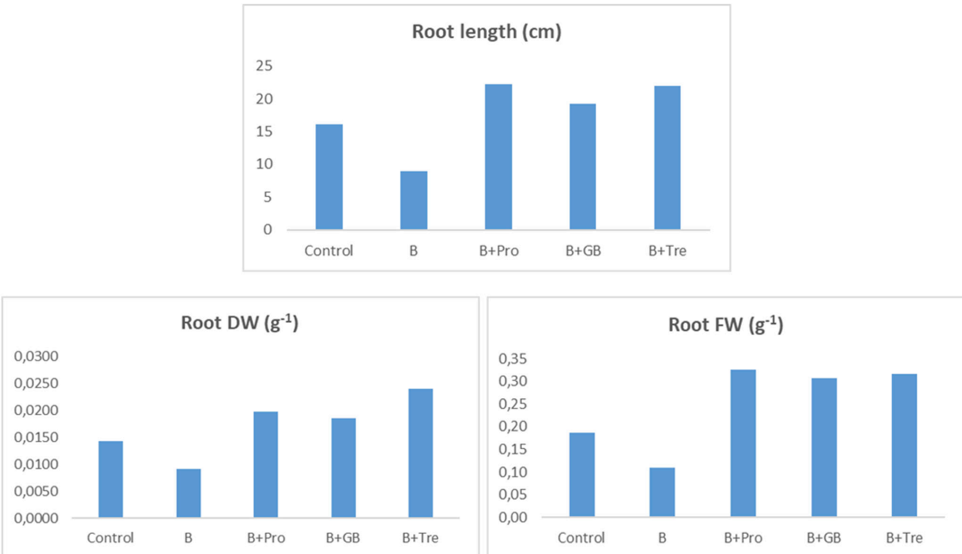

Figure 1. Effects of different treatments (Control, B, B+Pro, B+GB, B+Tre) on root growth parameters: root length, root dry weight (DW), and root fresh weight (FW)

Among the OPs tested, proline demonstrated the most pronounced impact on root length, resulting in an increase that was 2.5 times greater compared to plants under boron stress alone. Trehalose treatment, on the other hand, produced a notable 2.6-fold increase in root dry weight. Additionally, all OP treatments led to substantial increases in root fresh weight. These results clearly emphasize the effectiveness of osmoprotectants in promoting root growth and improving the overall resilience of wheat under boron toxicity, offering potential strategies to enhance plant tolerance in adverse soil conditions.

Boron toxicity also increased malondialdehyde (MDA) content by 35%, indicating enhanced oxidative stress. The application of OP significantly reduced MDA content, with the most notable reduction (40%) observed in the B + Tre group. Furthermore, electrolyte leakage, which increased by 75% under boron stress, was also mitigated by OP treatments, with the Tre + B group showing the greatest reduction of 25%, bringing values closer to control levels. Antioxidant enzyme activities were also affected by boron toxicity.

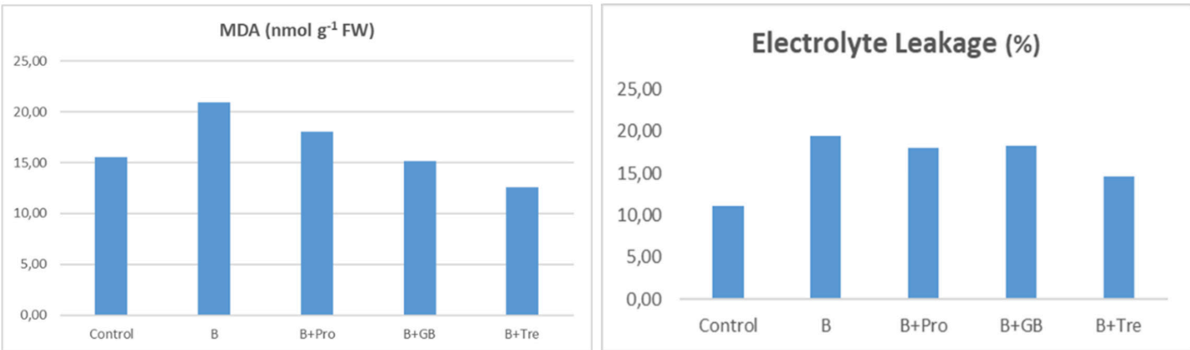

Figure 2. Effects of different treatments (Control, B, B+Pro, B+GB, B+Tre) on MDA content and electrolyte leakage (%) in plants

Peroxidase (POX) activity decreased by 23% under stress, but both proline and trehalose effectively enhanced POX activity by 23% and 78%, respectively. Notably, glycinebetaine did not enhance POX activity under boron stress. Catalase (CAT) activity dropped to 70% of control levels due to boron toxicity, but all OP successfully increased CAT activity, with trehalose showing the most significant enhancement—3.5 times higher than boron stress alone. These results highlight the potential of OP as a sustainable solution for enhancing plant resilience under boron toxicity. The exogenous application of proline, glycinebetaine, and trehalose not only improved growth and reduced oxidative damage but also enhanced antioxidant enzyme activities, thus contributing to better stress tolerance. Future research should focus on elucidating the molecular mechanisms underlying OP mediated stress tolerance and exploring the combined use of these OP with other agronomic practices to further improve stress tolerance and ensure stable crop productivity in challenging environments.

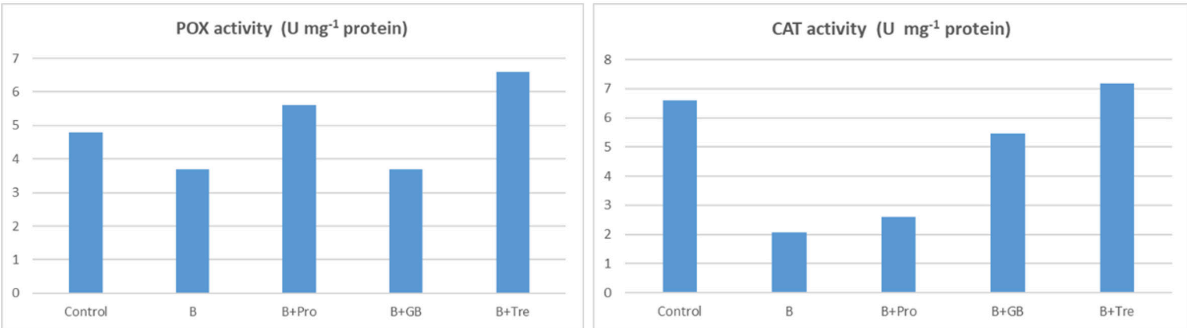

Figure 3. Effects of different treatments (Control, B, B+Pro, B+GB, B+Tre) on POX activity and CAT activity in plants

Discussion

The results of this study are consistent with previous research that highlights the positive impact of osmoprotectants (OP) on plant tolerance to stress. Numerous studies have demonstrated that proline functions as both an osmotic regulator and a scavenger of reactive oxygen species (ROS), which helps mitigate oxidative damage in various stress conditions, including salinity and heavy metal toxicity (Hosseinifard et al., 2022). Similarly, glycinebetaine has been widely recognized for its role in maintaining membrane integrity and protecting the photosynthetic machinery during abiotic stress (Huang et al., 2020). In this study, glycinebetaine was shown to reduce oxidative damage and enhance antioxidant enzyme activity under boron toxicity. However, its impact on peroxidase (POX) activity was less significant compared to proline and trehalose.

Trehalose, a disaccharide, has garnered attention for its ability to stabilize proteins and cellular membranes under stressful conditions. This study confirmed that trehalose was particularly effective in boosting catalase (CAT) activity and reducing malondialdehyde (MDA) levels, marking it as a potent agent in mitigating oxidative stress. Additionally, trehalose enhanced POX activity, suggesting a broader influence on the plant's antioxidant defense system. This makes trehalose a highly effective osmoprotectant against boron-induced oxidative stress. Previous studies have also proposed that trehalose not only acts as an osmoprotectant but is involved in signaling pathways that regulate stress-responsive genes (Nawaz et al., 2022).

A key indicator of membrane damage, electrolyte leakage, was significantly elevated under boron toxicity but reduced by the application of OPs. The Trehalose + B treatment group showed the greatest reduction in electrolyte leakage, further reinforcing the protective role of trehalose in preserving membrane stability. This aligns with earlier research showing that trehalose reduces membrane damage and improves stress tolerance in wheat and other crops (Chen & Murata, 2008).

The study's findings reveal that each OP exerts distinct effects, contributing to plant stress tolerance through different mechanisms. Proline was especially effective in promoting root length, whereas trehalose demonstrated superior performance in enhancing antioxidant enzyme activities and reducing oxidative damage. Although glycinebetaine effectively lowered MDA content and reduced electrolyte leakage, its influence on POX activity was less pronounced. These variations underscore the importance of understanding the unique functions of each OP to tailor their use for optimal stress mitigation in crops.

Looking ahead, future research should focus on unraveling the molecular mechanisms behind the actions of these OPs, particularly their involvement in signaling pathways and gene regulation. Additionally, investigating the combined use of different OPs or integrating them with other agronomic practices, such as biofertilizers or mycorrhizal inoculation, could offer new strategies to enhance crop resilience under multiple stress conditions. As climate change and soil degradation continue to threaten agricultural productivity, these sustainable approaches will be critical for ensuring food security and maintaining crop yields.

CONCLUSION

In conclusion, this study demonstrates the effectiveness of exogenously applied osmoprotectants (OP)—proline, glycinebetaine, and trehalose—in mitigating the harmful effects of boron toxicity in wheat. The results underscore the significant role these OPs play in enhancing plant stress tolerance by improving key growth parameters, reducing oxidative damage, and enhancing antioxidant enzyme activity. These findings are particularly important for maintaining agricultural productivity in regions where boron toxicity is a concern. Future research should focus on investigating the molecular mechanisms behind OP-mediated stress tolerance, as well as exploring their combined use with other agronomic practices that mitigate stress. Such research could pave the way for more resilient crop management strategies, contributing to food security in the face of increasing abiotic stress challenges driven by climate change and environmental degradation.

ACKNOWLEDGMENTS

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Effect of Biochar Particle Size on Aggregate Stability and Organic Carbon Content in a Sandy Loam Soil

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ABSTRACT

Biochar, a carbon-rich product derived from the pyrolysis of organic materials, has been recognized for its potential to improve soil health and enhance carbon sequestration. This study aims to evaluate the effects of different particle sizes of biochar and application doses on aggregate stability (AS) and organic carbon (OC) content in a sandy loam soil. Study was conducted under greenhouse conditions, biochar with four different particle sizes (<0.5 mm, 0.5-1.0 mm, 1.0-2.0 mm, and >2.0 mm) was applied at four different doses (0% as a control, 0.5%, 1.0%, and 2.0%) and wheat plants were grown. At the end of the experiment, aggregate stability and organic carbon values were measured. The effects of biochar on aggregate stability and organic matter content were found to be significant. Evaluating the particle sizes on AS values, it was found that the smallest particle size and the 1.0% application dose yielded the best results. While the effect of application doses on soil organic carbon content was found to be insignificant, the effect of particle size was significant. Like AS, the most effective particle size for OC was the smallest particle size. The highest increase in AS and OC compared to the control was 68% and 9% at the 0.5% application dose of the 1.0-2.0 mm particle size, respectively. In conclusion, this study demonstrated that application dose and particle size are crucial in determining the effectiveness of biochar. Knowing the optimal particle size and amount of biochar to apply for increasing aggregate stability, which indicates resistance to erosion especially in coarse-textured soils, is essential for sustainable soil management. These findings provide valuable insights for farmers and land managers aiming to enhance soil quality and achieve sustainable agricultural practices.

Keywords: Biochar, soil structure, soil organic carbon, sustainable soil management

INTRODUCTION

Aggregate stability (AS) is a crucial indicator of soil health, reflecting the soil's ability to maintain its structure and resist erosion under various environmental stresses. Stable soil aggregates enhance water retention, root penetration, and nutrient cycling, which are essential for sustainable agricultural productivity (Six et al., 2000). Improving aggregate stability, particularly in sandy loam soils, is vital for enhancing soil resilience and long-term fertility (Lal, 2015). Among various soil amendments, biochar—a carbon-rich product derived from the pyrolysis of organic materials—has shown considerable promise in enhancing soil physical properties, including aggregate stability (Glaser et al., 2002; Gülser, 2006; Gülser et al., 2015). However, the effectiveness of biochar in improving AS can vary depending on its particle size and application rate. Understanding these factors is critical for optimizing biochar use in different soil types and environmental conditions.

This study focuses on evaluating the effects of different biochar particle sizes and application doses on aggregate stability and organic carbon (OC) content in sandy loam soil. Conducted under controlled greenhouse conditions, the research aims to identify optimal biochar treatments that enhance soil structure and carbon sequestration, offering valuable insights for sustainable soil management practices.

MATERIAL AND METHOD

In this study, sandy loam soil samples were collected from a depth of 0-20 cm at the Bafra Experimental Station of Ondokuz Mayıs University, Faculty of Agriculture. The basic characteristics of the soil sample were as follows: sand content 68%, silt 19%, clay 13%, pH 7.65, electrical conductivity 0.32 dS/m, and organic carbon content 1.51%. The biochar material used was produced through the gasification of wood waste and properties were as follows: pH 9.42, electrical conductivity 0.31 dS/m, and organic carbon content 4.88%. Four different biochar particle sizes (<0.5 mm, 0.5-1.0 mm, 1.0-2.0 mm, and >2.0 mm) were incorporated into the soil (3kg per pot), with four different application doses (0% as a control, 0.5%, 1.0%, and 2.0%), under controlled greenhouse conditions. The experiment was conducted over a period of three months, during which the soil was irrigated with harvested rainwater to maintain field capacity. At the end of the experiment, soil samples were taken and analyzed for aggregate stability (Kemper and Rosenau, 1986) and organic carbon content (Kacar, 1994).

The variance analysis of the data was performed using one-way ANOVA to assess the significance of differences among the treatments. Additionally, a correlation graph was plotted to illustrate the relationship between aggregate stability and organic carbon content.

RESULTS AND DISCUSSION

The results of aggregate stability across different biochar particle sizes and application doses revealed significant differences (Table 1). The smallest particle size (<0.5 mm) resulted in the highest aggregate stability, followed by the largest particle size (>2.0 mm). This suggests that finer biochar particles may be more effective in enhancing soil structure, possibly due to their greater surface area, which facilitates better interaction with soil particles and contributes to the formation of more stable aggregates.

The aggregate stability values range from 18.4% to 33.6% and the highest aggregate stability was observed in the treatment with a biochar particle size of 1.0-2.0 mm at the 0.5% application dose (Figure 1). This finding aligns with previous studies that have demonstrated the positive impact of appropriately sized biochar particles on soil aggregation (Glaser et al., 2002; Blanco-Canqui, 2017).

Table 1. The effects of particle size and application dose on aggregate stability and organic carbon content

Particle size (mm)	Aggregate stability (%)	Organic carbon (%)
<0.5	26,29 ± 1,49	1,67 ± 0,02
0.5-1.0	23,92 ± 0,86	1,55 ± 0,02
1.0-2.0	23,28 ± 1,43	1,57 ± 0,03
>2.0	25,28 ± 1,71	1,62 ± 0,03
Application dose (%)		
0	20,15 ± 0,43	1,60 ± 0,01
0.5	25,13 ± 1,76	1,58 ± 0,04
1.0	27,35 ± 0,92	1,61 ± 0,03
2.0	26,14 ± 1,26	1,62 ± 0,02
Tukey HSD		
Particle size (Ps)	2.70*	0.06**
Application dose (Ad)	2.70**	ns
Ps x Ad	7.41**	0.17**

**: p<0.01, *:p<0.05 and ns: non-significant

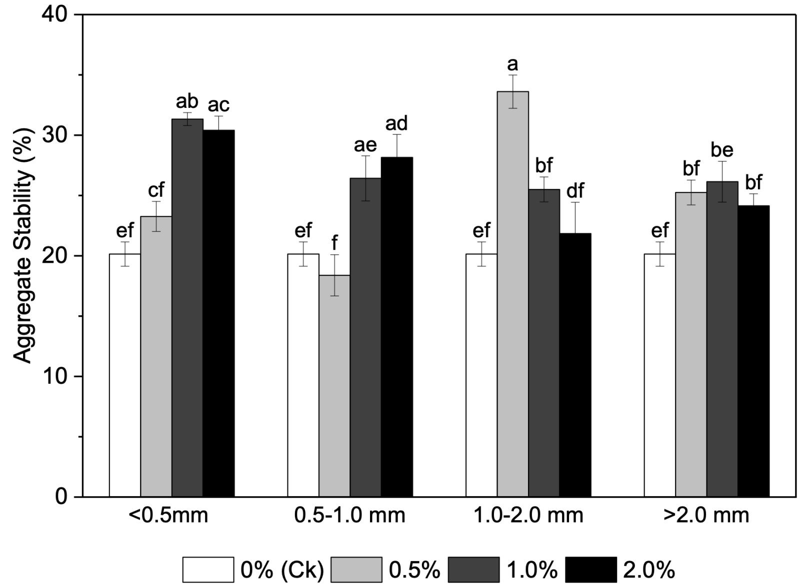

Figure 1. The effects of particle size and application doses on aggregate stability

The increase in aggregate stability with the 1.0-2.0 mm particle size could be attributed to the optimal balance between surface area and porosity, which enhances the binding of soil particles, leading to more stable aggregates.

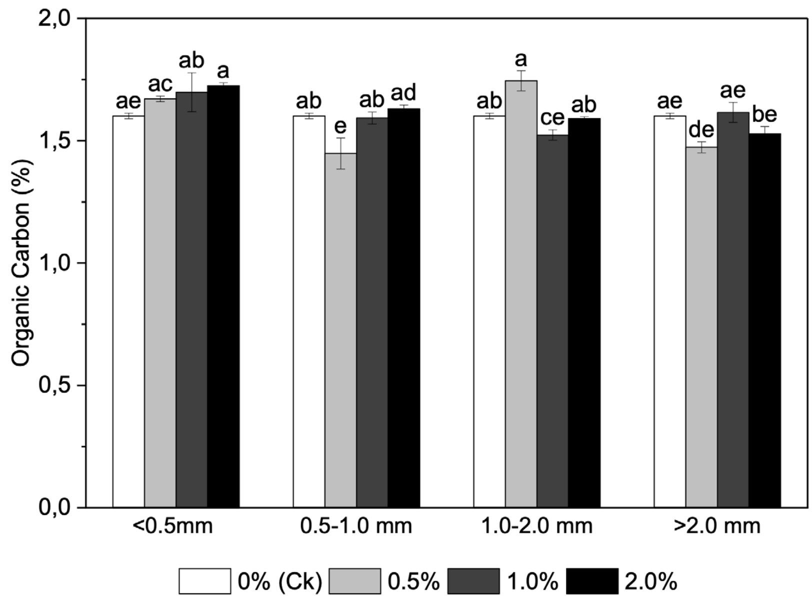

Figure 2. The effects of particle size and application doses on soil organic carbon content

The impact of biochar on soil organic carbon content was also analyzed, showing a positive response to biochar addition across all treatments (Table 1). The highest organic carbon content was observed in the <0.5 mm particle size while the 0.5-1.0 mm particle size had the lowest (Table 1). Although the differences in organic carbon content were statistically significant ($p < 0.01$), the relatively small variations suggest that particle size may have a more substantial impact on physical soil properties, such as aggregate stability, than on organic carbon levels. The highest organic carbon content was observed in the 1.0-2.0 mm particle size at the 0.5% application dose, mirroring the results for aggregate stability. The correlation between biochar application and organic carbon content indicates that biochar contributes to carbon sequestration in soil, consistent with findings from previous research (Lal, 2015; Blanco-Canqui, 2017).

While all particle sizes showed some increase in organic carbon content with biochar application, the effect was less pronounced compared to aggregate stability. This may be due to the fact that organic carbon accumulation is influenced by both the recalcitrant nature of biochar carbon and the enhancement of microbial activity, which is more complex and less directly related to particle size. The relatively high organic carbon content observed with smaller particle sizes (<0.5 mm) at higher doses suggests that finer biochar particles, despite lower aggregate stability, may still be effective in increasing soil organic carbon through enhanced microbial activity and surface interactions.

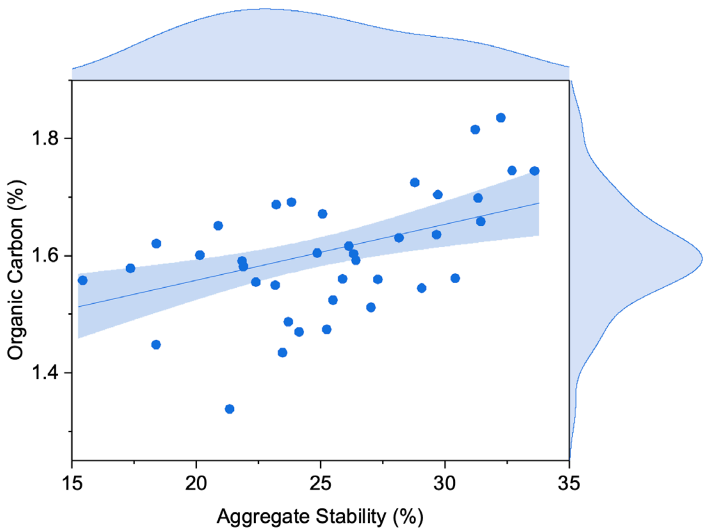

Figure 3. Relationship between organic carbon content and aggregate stability

The correlation analysis between aggregate stability and organic carbon content (Figure 3) revealed a positive relationship, indicating that improvements in aggregate stability are associated with increases in organic carbon content. This finding is consistent with the conclusions of Gülser et al. (2019), who emphasized that total organic carbon content is crucial for improving soil structural parameters, including aggregate stability. The study also highlighted that increasing soil organic matter enhances aggregate stability (AS) and mean weight diameter (MWD), with organic matter being more abundant in smaller aggregate fractions, thereby playing a vital role in soil structural development and sustainability. This correlation supports the hypothesis that biochar application not only improves soil structure but also enhances carbon sequestration in the soil. The observed correlation is consistent with the idea that stable soil aggregates protect organic carbon from decomposition, thereby contributing to long-term carbon storage in soil (Six et al., 2000; Lehmann and Joseph, 2015).

Overall, these results suggest that both biochar particle size and application dose are critical factors in determining the effectiveness of biochar as a soil amendment. These findings provide valuable insights for farmers and land managers aiming to improve soil quality through the targeted application of biochar.

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Effects of Sheep Wool Hydrolysate on the Growth and Antioxidant Enzyme Activity of Lettuce (Lactuca sativa L. Semental)on Boron Toxicity

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ABSTRACT

Boron (B) toxicity is an important agricultural problem and a limiting factor in yield, mainly in arid and semi-arid regions. Significant amounts of waste wool rich in proteins such as collagen, elastin and keratin, need to be used in alternative ways. Therefore, this study aimed to evaluate the waste sheep wool hydrolysate (SH) on B toxicity to lettuce. Boron was applied at 20 mg B kg-1 [(B), H3BO4], and SH was used as 1.5 mL kg-1 to the soil combined and separately. The SH treatment increased the dry weight of lettuce, whereas the B treatment decreased. Boron concentrations of the inner and outer leaves were decreased by SH treatment. Plant boron concentration was lower at the B+SH than at the B treatment. The nitrogen (N) concentration of the outer leaf was the highest at the B+SH and SH treatments. The SH treatment decreased the hydrogen peroxide (H2O2) content of lettuce. The superoxide dismutase (SOD) activity of the plant was high for the B treatment, yet ascorbate peroxidase (APX) and catalase (CAT) activity was high for the SH treatment. Similarly, relative chlorophyll was the highest for SH and then B+SH, control, respectively. There are no reports concerning the response of SH on B toxicity. Our results indicate that these parameters can be used to evaluate the B toxicity stress condition and help prevent the damage inflicted by B toxicity. The SH treatment positively affects the B stress condition, and the antioxidant defense system.

Keywords: Alkali hydrolysate, antioxidant defense system, boron, lettuce,

INTRODUCTION

Huge amount of sheep wool is a waste and the hydrolysate form of it is a new use area for agriculture (Akca et al., 2022). Amino acid has a fundamental role in protein, which is an essential element in biological parameters materials and changes in its availability and metabolism (Popescu and Stanescu, 2024). Besides, it is an amino acid- rich material that can be used in stress conditions, which has an effect on the biochemical and metabolism of plants (Hasanuzzamana et al., 2019) Wool is a fibrous raw material containing around 95% pure keratin by weight (Wang et al., 2016). As a biochemical point sheep wool is a keratinacious material, which contains about 20-25% protein should represent the good origin of nitrogen for plants (Gousterova et al., 2003). On the other hand, amino acids reduce oxidative stress in plants by decreasing the ROS mechanism (Souri, 2016; Teixeira et al., 2017).

Boron (B) is an essential plant nutrient needed for plant growth (Riaz et al., 2021). The B deficiency and toxicity are common in agricultural crops. The B concentration of soils is known for areas in which agriculture is practiced, because of the effects on crop yields (Reid, 2013). The high soil B was determined especially in areas such as Israel, Turkey, and Syria, respectively (Ravikovitch et al., 1961; Avci and Akar, 2005; Ryan et al., 1998) and others in which arid- semi-arid regions. The mechanisms of B toxicity involve interference with cell wall structure, disruption of membrane integrity, and disturbance in various metabolic processes (Riaz et al., 2021)

The reactive oxygen species (ROS) accelerate the degradation of chlorophyll and minimize the photochemical efficacy of antioxidants, and especially, damaging lipids, proteins, and nucleic acids, leading to lipid peroxidation, protein and DNA degradation (Bouzroud et al., 2023). Plants synthesize the antioxidant enzymes such as catalase (CAT), superoxide dismutase (SOD), and ascorbate peroxidase (APX) that the Sod has a role on converting $O2^-$ to H2O2 and then The CAT and APX has a role on reduction of H2O2 to H2O (Sahin et al., 2017a). SWool is an organic waste material, and is generally used in textile industry. Since, it is a keratin rich waste, which is a good source as a wool composting fertilizer and stress condition etc. (Hasanuzzamana et al., 2019; Petek and Logar, 2021). The aim of the study was to evaluation of effect of SH on boron toxicity, together with the function of the antioxidant mechanism on the lettuce plants.

MATERIALS AND METHODS

Preparation of Sheep Wool Hydrolysate

The SH hydrolyzed using an alkaline hydrolysis method, which added 1% NaOH and 5% KOH, described by Nustotova et al. (2006).

Soil Conditions and Analysis

The soil was taken from the 0-30 cm plow layer of the experimental fields. The following soil properties were carried out using the methods described by Page and Keeney (1982)

The soil was clay loam in texture, CaCO3 was 66.9 g kg-1, pH (1:2.5 water) 8.33, EC 0.38 dS m-1, organic matter 28.9 g kg−1, total N 2.80 g kg−1. The NaHCO3-available P was 12.3 mg kg−1, NH4OAc extractable K, Ca, and Mg were as 411, 5975, and 688 mg kg−1, respectively. DTPA-extractable Fe, Zn, Mn and Cu were 5.6, 1.1, 22.7 and 3.1 mg kg−1 respectively.

The experiment was conducted in the naturally lit greenhouse at Ankara University, Faculty of Agriculture, Turkey. The plants were grown in polyethylene pots each filled with 1 kg soil. At the experiment lettuce (Lactuca sativa L. cv Sementel) were grown. Lettuce seedlings, with one plant per pot, were sown in each pot on October 13, 2022 and harvested on December 23, 2022. For the B and N concentrations, plant leaves separated as inner and outer. Throughout the experiment, the plants underwent daily rotation and were irrigated to maintain approximately 70% of the field capacity by weighing the pots until harvest. For the basal fertilization, before the plants were sown, 100 mg N kg-1 and 50 mg P kg-1 were applied from ammonium nitrate and KH2PO4 to all pots, respectively. The treatments consist of control, boron (B) (20 mg B kg-1, H3BO4), 1.5 mL SH kg-1 soil (SH) anda combined form of B+ SH (20 mg B kg-1+1.5 mL SH kg-1). After the harvest, the plants were washed with purified water. The fresh weight of the plants was recorded and then dried in a forced-air ovenat 65°C and the dry weights were recorded. Finally, all plant samples were ground for analysis.

Determination of Elemental Concentrations of Waste Sheep Wool Hydrolysate and Plants With Antioxidant Enzyme Analysis of Plants

One gram of ground plant material or SH was weighed into Erlenmeyer flasks, and then 40 mL of a mixture prepared in a 4:1 ratio of HNO3:HClO4 was added. The mixture was boiled on a hot plate. The samples were diluted to a volume of 50 mL with reverse osmosis water and then, filtered by Whatman 42 filter paper. Elemental concentrations of the plant and SH samples were determined by using ICP-OES (Perkin Elmer 1200 V) (Sahin et al., 2017b). The total N concentrations of both the plant and SH samples were determined using the Kjeldahl method, following the procedure by Walinga et al. (1989).

All enzyme extraction procedures were conducted under controlled temperature conditions (0-4°C) to maintain sample integrity. Samples were taken from the youngest matured leaves and prepared for enzyme extraction by Sahin et al. (2017a). The specific activities of the enzymes were determined using the following methods: Superoxide dismutase activity was assayed using the nitroblue tetrazolium method as described by Gong et al. (2002). Ascorbate peroxidase activity was determined by Nakano and Asada (1981). Catalase activity was assessed by Cakmak et al. (1993). Hydrogen peroxide (H2O2) content in the shoots was determined calorimetrically, following the procedure outlined by Mukherjee and Choudhuri (1983). Relative chlorophyll readings just before harvest (between 11:00 and 12:00) were recorded from the youngest fully matured leaf of lettuce in each pot using a chlorophyll meter (CM 1000, Spectrum Tech. Inc. USA).

Statistical analysis

The experimental design was completely randomized with four replications. One-way ANOVA was performed using Minitab software (Minitab 17), and mean comparisons were carried out using Duncan's Multiple Range Tests.

RESULTS

The dry weight of lettuce plants, and B and N concentrations of inner and outer leaves of lettuce were given in Table 1. The highest dry weight was determined in SH treatment. The B concentrations of both leaves were statistically higher at the B and B+SH treatments. The N concentrations of the inner leaves were not statistically important. In contrast, the N concentrations of the outer leaves of lettuce were higher B+SH, control and SH treatment in which there was no statistical importance between treatments.

Table 1. Effect of waste sheep wool hydrolysate on dry weight, B and N concentrations of lettuce plant grown in B toxicity

Treatment	Dry weight g plant-1	Inner Leaf	Outer Leaf	Inner Leaf	Outer Leaf
		B mg kg-1		N g kg-1	
Control	2.46±0.12 b	37.0±1.13 b	47.8±10.3 b	4.17±0.16	3.67±0.04 b
B	2.38±0.14 b	83.4±2.14 a	176±6.75 a	4.58±0.13	3.74±0.12 b
SH	3.40±0.17 a	31.1±4.45 b	51.6±6.68 b	4.55±0.13	3.84±0.15 ab
B+SH	2.64±0.21 b	72.7±2.50 a	137±16.4 a	4.71±0.12	4.31±0.13 a
F	8.17**	84.0**	35.0**	2.96ns	6.00**
LSD	0.71	12.2	46.5	-	0.51

Based on Duncan's multiple range test, different letters in each column represent significant differences at $p<0.05$ level. ** $p< 0.01$; ns: non significant

The content of H_2O_2 in lettuce plants was statistically significant and the content of H_2O_2 was decreased by the SH treatment. The B treatment resulted in the highest SOD activities in plants. The APX and CAT activity of plants were higher in SH applied condition. Moreover, the B treatment determined the lowest APX and CAT actives. The relative chlorophyll content of plants was higher at the B+SH, but there was no statistical difference between control, SH and B+SH SH treatments (Table 2).

Table 2. Effect of waste sheep wool hydrolysate on relative chlorophyll, content of H2O2, SOD, CAT and APX enzyme activity of lettuce plant grown in B toxicity

Treatment	Relative chlorophyll	H2O2 mmol kg-1 FW	SOD Unit	APX mmol g-1 Fw min-1	CAT mmol g-1 Fw min-1
Control	147±8.70 ab	85.3±1.10 b	202±12.3 b	2.51±0.23 bc	0.51±0.01 b
B	140±1.11 b	127±1.55 a	262±17.6 a	1.82±0.22 c	0.32±0.01 d
SH	169±7.08 a	53.5±0.68 d	158±0.77 b	3.80±0.12 a	0.57±0.02 a
B+SH	143±5.11 ab	72.0±3.82 c	192±8.02 b	2.99±0.15 b	0.44±0.01 c
F	4.52*	207**	14.3**	19.7**	63.5**
LSD	26.7	6.66	49.5	0.81	0.06

. Based on Duncan's multiple range test, different letters in each column represent significant differences at $p<0.05$ level. ** $p< 0.01$; * $p< 0.05$; ns: non significant

DISCUSSION

With the SH treatment, dry weight increased. This means that the effect of protein contents on plant responses to abiotic stresses is fundamental to improving crop plants and obtaining sustainable plant growth (Hasanuzzamana et al., 2019). Similarly, by adding SH combined with B or separate treatment, content of N was increased. The effects of hydrolysates on plants include the carbon and N metabolism, an increase in nutrient uptake, and an improvement of water and nutrient use efficiencies (Balan et al., 2023). Similarly to our results, Wang et al. (2013) was reported that the SH had increased protein contents and showed more tolerance to stress. Boron concentration in the inner and outer leaves increased with B addition whereas, by the addition of SH, B was decreased. Moreover, leaves B concentrations decreased significantly with SH and control treatments compared to B and B+SH. There was no report of the effect of SH on boron toxicity. But by the effect of protein source material addition, the amino acid is a well-known biostimulant, which has positive effects on plant growth and significantly response on which caused by stresses condition (Kowalczyk and Zielony, 2008; Alves et al., 2011; Souza et al., 2018; Najafikhan-Behbin et al., 2019).

Our results show that relative chlorophyll was increased by the SH and B+SH treatment. The application of SH is the increase in photosynthetic pigments such as chlorophyll, which play an important effect in chlorophyll synthesis due to the high amino acid content (Asadi et al., 2022). Stress causes the accumulation of reactive oxygen species (ROS) such as hydroxyl radicals (OH·), H2O2, singlet oxygen (1O2), superoxide radical (−O2). The scavenging activities of antioxidant defense mechanism decreased the effect of ROS. The plants respond to oxidative stress by elevating the enzymatic activity such as SOD, CAT and APX (Ahmad et al., 2020). The highest content of H2O2 was determined due to the B treatment. Besides, addition of SH in B applied condition, content of H2O2 in leaves were decreased and, the lowest content of H2O2 were determined in SH treatment. The highest SOD activity was determined by the B treatment whereas CAT and APX enzyme activity increased applied SH when compared to the B treatments. Our results showed similarity with Easlan et al. (2007), in which researchers declared that B toxicity reduced antioxidant enzymes such as SOD, CAT and APX activities B-stress-induced. The ROS are inevitable products of metabolism and are eliminated by the antioxidant mechanism (Sahin et al., 2017a; Jingyun et al., 2023). In addition, amino acids are known to block free radical-mediated peroxidation chain reactions by converting the oxygen radicals to more stable radicals (Sheng et al., 2022; Ali et al., 2019). Hydrolysates were known due to their beneficial effects on plant growth, especially under environmental stress conditions.

CONCLUSION

The sheep wool hydrolysate showed the potential of tailoring the keratin molecule for bioactive additive preparation. There is study is the first research effect on the sheep wool hydrolysate on boron toxicity. The sheep wool hydrolysate alleviates B toxicity by possibly preventing oxidative membrane damage by lowering B uptake and elevating tolerance to excess B within the lettuce leaves.

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Composting of Hazelnut Husk and Prunning Residues

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ABSTRACT

Composting agricultural waste and residues and returning them to agricultural lands and nature is important both to compensate for the lack of organic matter in the soil and to prevent environmental problems. In this study, hazelnut husk and pruning waste obtained from a hazelnut orchard were composted under aerobic conditions by inoculating with microorganisms extracted from forest soil and fresh farmyard manure. The organic waste materials were laid down as a pile in the windrow composting unit and composted around 60-70% moisture condition. Temperature, pH, EC, organic C, C/N ratio, total P, total K, CO2 production and microbial biomass C contents of the compost pile were determined during the 45-day composting period. According to the results, the temperature of compost pile reached thermophilic phase after 6 days, and the highest temperature was measured as 56°C at the 14th day. The C/N ratio and pH of the compost pile were changed from 60 and 8.53 initially to 30.13 and 7.38 at the end of 45 days, respectively. While the total P content increased by approximately 30%, there was no significant change in the total K content. It can be concluded that hazelnut husk and pruning waste can be successfully composted with windrow method with microbial inoculation around 7 weeks without using any other farmyard manure or other waste to reduce C/N ratio.

Keywords: C/N ratio, hazelnut husk, microbial inoculation, pruning waste

INTRODUCTION

Agricultural waste can be divided into four primary categories: agro-industrial waste, livestock waste, crop residues, and aquaculture waste. As global agricultural production continues to rise, both crop harvest waste and organic waste from the agricultural industry are increasing steadily. These plant-based wastes are not only a rich source of organic matter but also hold significant potential as plant nutrients. Hazelnut husk, a crop residue, is one such example. Comprising approximately 95% organic matter, it is a substantial agricultural waste.

Turkey, the leading global producer of hazelnuts, produces about 600,000 tons annually, resulting in an estimated 200,000 tons of hazelnut husk waste on a dry basis (Karaosmanoğlu, 2022). After harvesting, 200g of 1 kg of fresh hazelnuts is released. The hazelnut waste materialis an organic waste and can be applied to soils in agricultural lands. In terms of plant nutrient content, the waste is low in terms of N and P, sufficient and high in terms of K and micro elements, rich in organic matter, and has appropriate pH and electrical conductivity values (Kacar and Katkat, 1998). Despite the potential uses of this lignocellulosic biomass, hazelnut husks are typically disposed of by burning or simply left in fields, wasting both their volume and nutrient potential (Guney, 2013; Ceylan, 2014).

A large part of the hazelnut growing areas consists of sloping lands. This situation makes it difficult to use agricultural mechanization methods in the implementation of cultural processes. At the beginning of cultural processes are such as cleaning the bottom shoot, pruning, and fertilization.Approximately 1.7 million tons of waste is generated annually after cleaning the bottom shoot and pruning processes (Anonymous, 2023).

In this study, hazelnut husks and pruning wastes obtained from hazelnut orchards (2:1 ratio) were inoculated with microorganisms obtained from forest soil and fresh farm manure and were tried to be composted under aerobic conditions by using windrow composting method.

MATERIAL AND METHOD

The size of the pruning waste was reduced to 1-5 cm before composting. Hazelnut husks and pruning wastes were collected from hazelnut orchards in the region. The size of the pruning waste was reduced to 1-5 cm before composting. Afterwards, hazelnut husks and hazelnut pruning wastes were mixed at a ratio of 2:1 and laid in piles in the composting unit of Ondokuz Mayıs University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition.

Fresh cow manure, forest soil and urea (46% N) fertilizer were mixed in water, filtered and homogeneously added to the pile to accelerate microbial activity. The compost pile was mixed daily, and the moisture content was kept at around 60-70%.

The pH, EC, moisture and temperature of the compost pile were measured daily during the composting period. C/N ratio, total P, total K, CO_2 production and microbial biomass C contents were determined at 4-day intervals.

Table 1. Following methods were used for determining the compost properties

Properties	Method
pH	1:10 (w/v), compost: water mixture by pH meter (Rowell, 1994)
EC	1:10 (w/v), compost: water mixture by EC meter (Rowell, 1994)
Organic Carbon	Dry combustion (Ryan et. al, 2001)
Total N	Kjeldahl method (Bremner, 1965)
C/N Oranı	By calculation as a result of organic carbon and N analysis
CO2 Production	(Anderson, 1982)
Microbial Biomass Carbon	(Anderson and Domsch, 1978)

RESULTS AND DISCUSSION

According to Table 1, the temperature of the compost pile reached the thermophilic phase (43-66°C) after 6 days and this situation continued for up to 20 days. The highest temperature was measured as 56°C on the 14th day in the thermophilic phase. After 20 days, the temperature of the compost pile began to decrease and balanced with the environmental temperature on the 45th day.After the 45th day, the composting process continued. However, since there was no change in temperatures, the end of composting process was noted as the 45th day.Although composting is effective under mesophilic conditions, many researchers recommend maintaining the heap temperature between 43-65 ºC for some time (Nielsen and Berthelsen, 2013; Gray and Sherman, 1969; Poincelot, 1972). The removal of pathogenic microflora, weed seeds and flying larvae largely occurs under thermophilic temperature conditions, with a critical temperature of 55 ºC for pathogens and 63 ºC for weed seeds (Fernandes et al., 1988). In this study, the highest temperature of 56 ºC was determined within 14 days of thermophilic temperature conditions, indicating that pathogens and weed seeds were inactivated during this composting period.

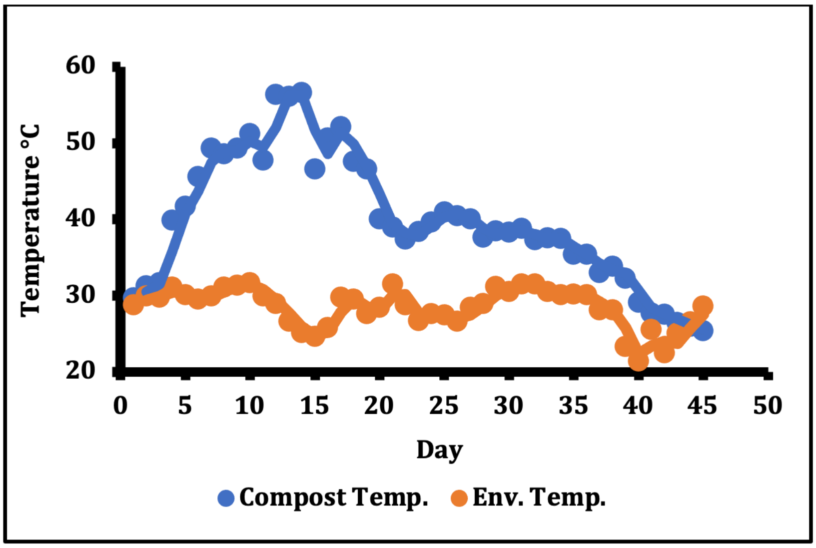

Figure 1. Changes of the temperatures during composting process

C/N ratio and pH values of the compost pile were changed from 60, 8.53 initially to 30.13, 7.38 at the end of 45 days respectively. C/N ratio was initially measured at around 22 with the addition of nitrogen to stimulate microorganism activity. In time, the conversion of nitrogen in the compost pile to ammonia may cause an increase in the pH value and with this increase, ammonia nitrogen may be released in the form of gas, causing a decrease in the pH value and an increase in the C/N ratio.

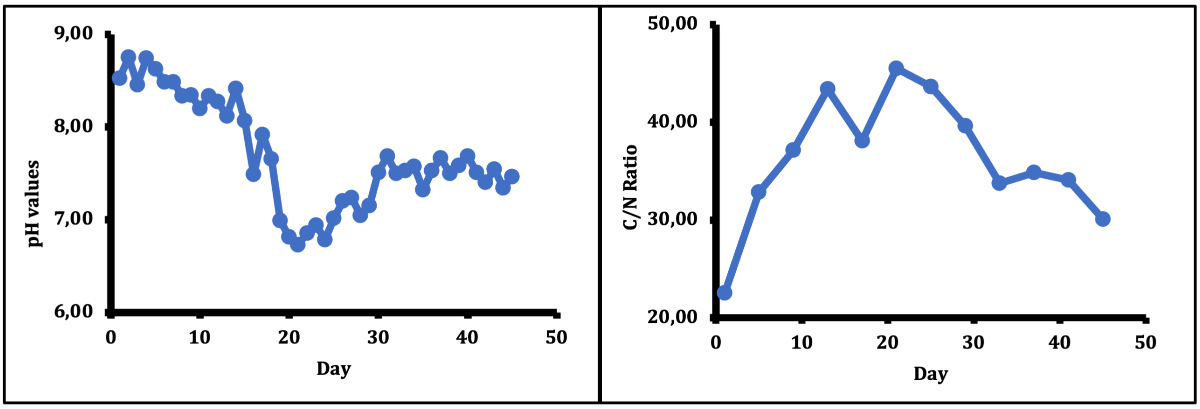

Figure 2. Changes of the pH and C/N ratio of the compost pile

In general, it is stated that the composting process can take place in a pH range of 3-11 (Bertoldi et al 1983), while composting proceeds efficiently between pH 4.5 and 5, but not as fast as in neutral (pH 7.0) conditions. Changes in pH can be caused by organic acids released as a result of microbial activity and ammonia released from the compost (Iqbal et al., 2010; Sundberg et al., 2004). The greatest effect of the pH of the medium is on the N content because when the pH is greater than 8.5, nitrogenous compounds can be converted to ammonia and the nitrogen in the medium can be lost from the medium in the form of gas, while a pH of less than 8 reduces the formation of ammonia (Bilen and Sezen, 1993).

The total P value of the compost pile increased from 0.08% at the beginning to 0.11% at the end of composting. Approximately 30% increase in total P content occurred. Total K content also increased, but not as much as total P content. Eneji et al. (2001) reported that they obtained similar results to our study in the compost they made from livestock feces. They found that the total P content of the compost increased much more than the total K content.

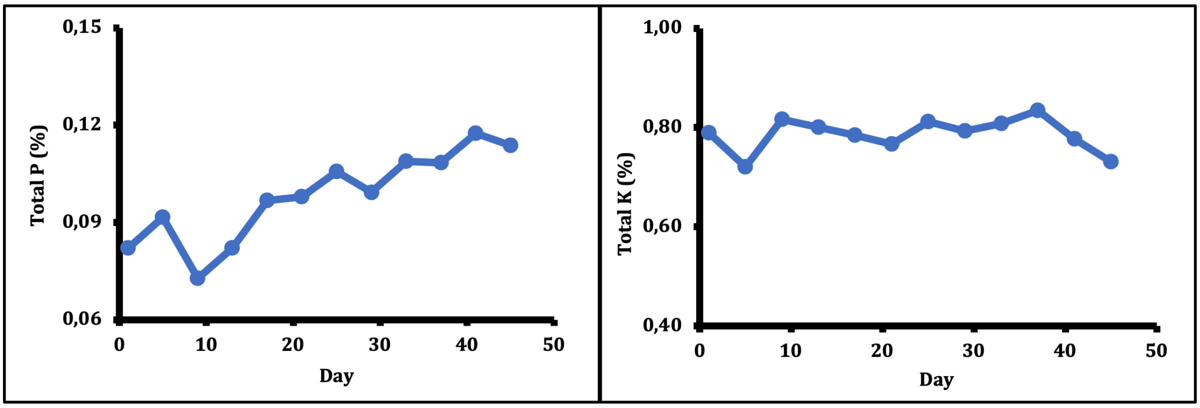

Figure 3. Changes of the total P and total K content of the compost pile

Figure 4 shows that the microbial biomass carbon and CO2 production amounts measured in the compost pile were highest in the initial inoculation phase. The highest measurement values were found in the first 20 days of the composting process that including the 14-day thermophilic phase. Tam (1995) investigated the changes in microbiological properties of swine manure during in-situ composting and reported that the biomass carbon content in the environment increased at first and then decreased, and the biomass carbon value at the end of composting was higher than at the beginning. Cayula et al. (2012) found in their composting study that high CO2 production occurred in the first 20 days of composting, corresponding to the highest temperatures. They found significant correlation between CO2 production and temperature values.

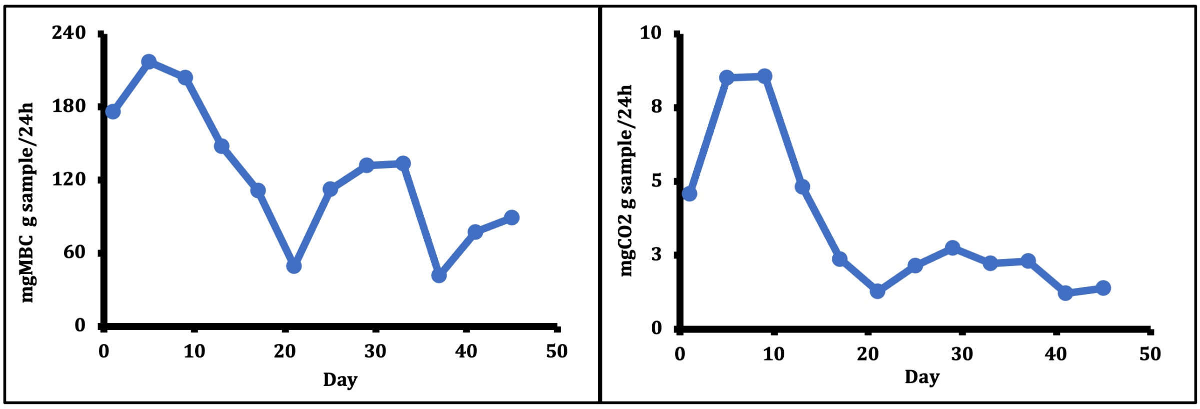

Figure 4. Changes of the Microbial Biomass Carbon and CO2 production of the compost pile

CONCLUSION

It can be concluded that hazelnut husk and pruning waste can be successfully composted with windrow method with microbial inoculation around 7 weeks without using any other farmyard manure or other waste to reduce C/N ratio. In addition, conditions such as mixing, and moisture content must be ensured throughout the entire composting process.

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Assessment of Nutritional Status of Apples Grown in Semi-Arid Regions by Soil and Leaf Analysis

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ABSTRACT

Plants require balanced nutrition for sustainable production and improved yield and quality. This study aimed to assess the current nutritional status of apple trees extensively cultivated in the Goksun district of Kahramanmaras province through soil and leaf analysis, and to establish correlations with soil properties. To achieve this, the texture and certain chemical properties (pH, EC, lime, active lime, OM) of soils were analyzed from 25 different apple orchards at two depths (0-25 cm; 25-50 cm), along with concentrations of various macro and micronutrients in both soil depth and leaf samples. According to the study findings, the prevalent soil texture was sandy loam, with soil pH showing a slightly alkaline at both depths. However, organic matter (OM) levelsin the soils were inadequate at both depths. While the levels of exchangeable potassium (Kexc), calcium (Caexc), magnesium (Mgexc) and extractable copper (Cuex) were adequate in the soils, 30% of the soils showed deficiencies in available phosphorus (PA). The concentration of extractable iron (Feex) was low in 20% of the soils, zinc (Znex) was deficient in almost half of the soils, and boron (BA) was deficient in all of the soils. Leaf analyses revealed deficiencies in some macro and micronutrients, and significant statistical relationships were identified between certain physical and chemical properties of soils and nutrient contents in the leaf samples. According to the data obtained; It is recommended to apply fertilizers containing K, P and micro elements to a soil depth of 15-20 cm, and to include B and zinc in the fertilization program in the region.

Keywords: Goksun, apple, plant nutrients, soil properties

INTRODUCTION

Due to Türkiye's favorable climate conditions for fruit cultivation, it ranks among the top countries in the world in terms of fruit production (Keskin et al., 2009). Of the 86.442.716 tons of apples produced globally, Türkiye accounts for 4.300.486 tons, which is approximately 5%. Despite variations in production levels, Türkiye generally holds the third position in apple cultivation worldwide (FAO, 2023). In Turkey, the ranking of apple plantations by province is as follows: Isparta, Karaman, Nigde, Denizli, Antalya, Konya, Mersin, Canakkale, and Kahramanmaras. In Kahramanmaras, apple production occurs on 49.695 hectares, with a total yield of 86.531 tons. Of this, 53.811 tons come from the Goksun district, where apple cultivation takes place on 29.500 hectares (TUIK, 2023). In Goksun district, where many fruits including apples are grown, a shift from traditional to modern cultivation practices has been observed. To achieve high and quality yields, it is essential to have a good understanding of soil characteristics and to implement appropriate agricultural practices accordingly. In this context, as with other fruits, ecological factors such as climate and soil, as well as cultural practices like irrigation, pruning, pest control, and plant nutrition, affect the growth and yield of apples.

The aim of this study is to examine the macro and micro nutrients in the apple orchards soils, to evaluate the nutrition status of apples through soil and leaf analyses, and to determine the relationships between soil properties and nutritional status of theapples.

MATERIAL AND METHODS

Study Area

Goksun is a district located 60 km north of the city center of Kahramanmaras. The district has an elevation of approximately 1343 meters and is characterized by a semi-continental climate type. The average annual temperature in Goksun is 8°C, and the average annual precipitation is around 600 mm (Yalcıner, 2012).

Figure 1. The location of the study area on the map

The study was conducted in apple orchards located in various villages within the Goksun district. Soil samples were collected from 25 different apple orchards at two depths: 0-25 cm and 25-50 cm, using a random sampling method. In July, leaf samples were also collected from the same locations where soil samples were taken. The names of the areas where soil and leaf samples were collected (1.Temuraga, 2 and 3.Yagmurlu, 4 and 5. Hacıomer, 6,7,8,9 and10. Korkmaz, 11,12, 13, 14 and 15. Cardak, 16, 17, 18, 19 and 20. Ericek, 21, 22, 23, 24 and 25. Kamıscık) and their locations on the map are shown in Figure 1.

Soil samples collected from the orchards were analyzed for texture, soil reaction (pH), total salts, OM, lime, available phosphorus (PA), exchangeable cations (Caexc, Mgexc, Kexc), and extracted microelements withDTP (Feex, Znex, Cuex, Mnex) using methods commonly employed in Türkiye (Kacar, 1995). Available boron was extracted with 0.01 M $CaCl_2$ and 0.01 M mannitol and determined using an ICP-OES device (Cartwright et al., 1983). Active lime was determined using the method proposed by Yaloon (1957).For the leaf samples taken from the orchards, P was determined with colorimetric method, and macro and microelements were analyzed using AAS, N was the Kjeldahl method (Kacar, 1972). Active iron was determined according to Takkar and Kaur (1984).To determine the relationships between soil properties and the nutrient contents of the leaves, SPSS 13.0 software and Pearson correlation analysis were used (SPSS, 2013).

RESULTS AND DISCUSSION

Evaluation of Some Physical and Chemical Properties of Soils

Table 1 presents the min., max., and mean values of physical and chemical properties of soils. The soils of the orchards from which samples were collected fall into four different texture classes: 56% sandy loam, 36% loamy sand, 4% sandy, and 4% sandy clay loam. Based on the results, it can be said that the region has a suitable soil texture for apple cultivation. According to Saglam (2008), the pH values of soil samples at a depth of 0-25 cm show that 20% of the soils are neutral and 80% are slightly alkaline, while at a depth of 25-50 cm, 16% of the soils are neutral and 84% are slightly alkaline. Mitra (2003) has reported that the suitable pH for apple cultivation should be slightly acidic to neutral (pH 6.5-6.7). Therefore, it can be recommended to apply elemental sulfur to lower the soil pH (Derafshi et al., 2023).The levels of OM in the soils at a depth of 0-25 cm, according to the Ulgen and Yurtsever (1974), are categorized as 8% very low, 32% low, 12% medium, 20% good, and 28% very good. At a depth of 25-50 cm, the OM content of the soil is 16% very low, 40% low, 40% medium, and 4% good. According to the obtained data, more than half of the orchards have insufficient soil OM content. Significant positive relationships were found between soil OM content and the PA, Kexc, and BA contents of the soil.

Additionally, a significant positive relationship was found between OM and plant leaf K and B levels. This situation can be interpreted as a clear indication that OM positively affects the relevant nutrients. It is recommended to apply organic materials in areas with low soil OM content.The lime content of the soils, according to Ulgen and Yurtsever (1974), is classified as follows: at 0-25 cm depth, 4% of the soils are calcareous, 52% are moderately calcareous, 40% are highly calcareous, and 4% are very highly calcareous. At a depth of 25-50 cm, the lime contents are 4% calcareous, 52% moderately calcareous, 20% highly calcareous, and 24% very highly calcareous. Significant positive relationships were found between lime content and clay (r=.430*; .450**), pH (r=.475*; .528**), and active lime (r=.804** ; r =.766**), while significant negative relationships were found between lime content and soil and plant leaf Fe concentrations (r= -.476*; r =-.461*). This suggests that in the region, lime is present in the clay fraction, increases soil pH, and negatively affects iron uptake by plants. Additionally, the active lime content in the research area ranges from 0.9% to 16.5%, with an average of 3.7%. The active lime contents also showed similar results to those obtained for lime contents. To mitigate the negative effects of lime in the region, the use of organic fertilizers and elemental sulfur is recommended.

Table 1. Some physical and chemical properties of soils in the study area

	Clay (%)	Sand (%)	Silt (%)	pH	Salt (%)	O.M (%)	Lime (%)	Active Lime(%)
Min.	2.5	67.6	5.1	6.7	0.04	0.3	3	0.9
Max.	22.3	91.1	15.1	7.8	0.22	5.6	47.6	16.5
Mean (0-25 cm)	10.8±4.3	79.4±6.4	9.80±2.7	7.5±0.2	0.11±0.04	2.8±1.5	14.6±9.8	3.5±2.9
Mean (25-50 cm)	12.5±4.6	78.3±5.4	9.26±2.9	7.5±0.2	0.10±0.04	1.8±0.7	16.1±11.4	3.8±2.9

Evaluation of Macro and Micro Nutrient Concentrations in Soils of the Study Area

The concentrations of PA, Kexc, Caexc, Mgexc, Feex, Znex, Mnex, and Cuex in soil samples taken from orchards at depths of 0-25 cm and 25-50 cm in the study area are presented in Table 2. According to the FAO (1990) classification, the PA concentrations at the 0-25 cm depth are categorized as follows: 12% low, 40% adequate, and 48% high. At the 25-50 cm depth, the PA levels are classified as 4% very low, 48% low, 36% adequate, and 12% high. The data indicate that approximately half of the soils at the lower depth (25-50 cm) have low PA content. This suggests that P fertilizers applied at the surface react with soil components (clay, lime, Ca, and oxides) and concentrate at the surface, preventing P from reaching the lower depth where plants primarily feed. For balanced P nutrition in the apples grown in the region, it is recommended to apply P containing base fertilizers to a depth of 15-20 cm. A positive correlation was found between P content in the upper soil layer (0-25 cm) and OM (r=.398**). This significant positive relationship between OM and PA suggests that OM improves P uptake by plants.According to the classification by FAO (1990), the Kexc levels in the soils are as follows: at a depth of 0-25 cm, 8% are low, 64% are sufficient, and 28% are high. At a depth of 25-50 cm, 24% are low, 68% are sufficient, and 8% are high. In the region, the amount of Kexc decreases as one moves from the upper layer (0-25 cm) to the lower layer (25-50 cm). Although the Kexc content is generally sufficient in the upper layer, the fact that 24% of the lower layer soils are deficient indicates the need for K fertilization in these areas. At a depth of 0-25 cm, a positive correlation was found between the Kexc variable and pH (r=.404*), OM (r=.572**), soil PA (r=.412**), soil Caexc (r=.393**), and plant Ca content (r=.352*). In the lower layer, significant positive relationships were found between Kexc and OM (r=.494**), soil P (r=.535**), and soil Caexc (r=.533**). The significant positive relationship between OM and Kexc indicates that OM positively affects the Kexc content. In the study area, the Caexc content in the upper soil layer (0-25 cm) is categorized as 12% sufficient and 88% high. In the lower depth (25-50 cm), the Caexc content is 10% sufficient, 88% high, and 2% very high (FAO, 1990). Regarding Mgexc content, 46% of the soils are sufficient and 54% are high. No deficiencies in Caexc and Mgexc have been observed in the soils. According to the classification proposed by Lindsay and Norvell (1978), the Feex content in the soils is as follows: at both depths, 20% of the soils have low Feex content, and 80% have high Feex content.

Correlation analysis at a depth of 0-25 cm revealed significant negative relations with clay (r=-.554**), pH (r=-.686**), active lime (r=-.460**), Caexc (r=-.562**), and lime (r=-.496*). Similar significant negative relationships were found at the lower depth as well (correlation table not provided). Low Feex in the soils are typically observed in areas with high clay, lime, and pH values. The negative relationship between Feex content, pH and lime in soils suggests that high pH and lime levels may hinder or reduce Fe uptake by plants. It has been reported that at high lime and pH, Fe^{2+} ions oxidize to Fe^{3+} ions, precipitating as $Fe(OH)_3$ compounds, which leads to decreased Fe uptake by plants (Turan and Horuz, 2012). In areas with insufficient Feex, it is recommended to apply OM, humic acids, Fe-containing fertilizers, and Fe chelated fertilizers.

Table 2. Concentrations of macro and micronutrients in the soils of the study area

	PA	K	Ca	Mg	Fe	Mn	Cu	Zn	B
					mg kg-1				
Min.	2.3	70.7	3090	209.7	1.4	9.5	0.4	0.1	0.1
Max.	70.1	619.6	10149	1322.3	16.8	95.9	7.2	5.0	0.5
Mean (0-25)	29.9±18.0	309.5±152.8	6149±1674	515.7±184.9	7.4±4.2	29.7±20.6	2.37±1.5	1.8±1.2	0.2±0.1
Mean (25-50 cm)	12.4±11.6	217.1±114.1	6536±1905	507.2±269.5	6.3±2.6	25±13.4	1.45±0.7	0.42±0.3	0.1±0.08

At the 0-25 cm depth, Znex concentrations are classified as 4% very low, 12% low, 48% adequate, and 36% high. At the 25-50 cm depth, Znex levels are 12% very low, 68% low, and 20% adequate. Despite generally adequate to high Znex levels in the upper soil, Znex deficiency increases proportionally at the lower depth. Considering that apple trees primarily access nutrients from the 25-50 cm soil depth, it can be concluded that approximately 80% of the soils have inadequate Znex content. Therefore, it is recommended to apply Zn-containing fertilizers in the region.When examining the concentrations of Cuex and Mnex in the study area, no deficiencies of Cuex or Mnex were observed. At the 0-25 cm depth, significant negative correlations were found between Mnex and soil clay (r = -.402*), pH (r = -.402*), and Caexc (r = -.402*). A similar situation was observed at the 25-50 cm depth concerning soil pH. These findings indicate that soil properties may negatively impact the availability of Mn.According to the classification of BA content, all orchards exhibit BA deficiencies at both soil depths. Thus, the application of B-containing fertilizers is strongly recommended for the region. Significant positive correlations were found between BA and OM (r = .631**; .370**), PA (r = .475**; .669**), and Caexc (r =.303*;.334*) at both soil depths. These relationships suggest that an increase in soil OM is associated with higher concentrations of B and other nutrients.

Evaluation of Nutrient Element Concentrations in Apple Tree Leaves

The minimum and maximum values of some macro and micronutrients in leaf samples taken from apple orchards are presented in Table 3. According to the classification by Jones et al. (1991), N deficiencies were detected in all of the leaf samples from the apple orchards. It has been reported that adequate N fertilization enhances the healthy growth of fruit trees, improves fruit bud formation, fruit quality, and yield (Stiles, 1994). Therefore, balanced N nutrition in apples is considered likely to positively impact yield and quality in the region. The P content of the fruit leaves, according to the classification by Jones et al. (1991), is adequate in all orchards except for one. The P content of the leaves ranges from 0.14% to 0.23%, which is very close to the lower boundary of the recommended sufficiency range. Therefore, attention should be given to P nutrition of plants, and P fertilizers should be applied to a soil depth of 15-20 cm during planting.

Table 3. Concentrations of macro and micro nutrients in apple tree leaves

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe mgkg-1	A.Fe mgkg-1	Zn mgkg-1	Cu mgkg-1	Mn mgkg-1	B mgkg-1
Min.	0.47	0.14	0.7	0.97	0.31	148.9	19.2	16.7	7.3	24.4	9.5
Max.	1.84	0.23	1.97	2.50	0.87	391.3	43.4	54.4	141.4	97.0	27.8
Mean	1.05±0.3	0.17±0.01	1.46±0.35	1.41±0.39	0.47±0.10	264.3±56.9	29.7±7.1	25.1±7.5	18.8±28.2	49.2±20.5	18.9±5.2

In leaf samples from the research area, the K levels are inadequate in 48% of the samples according to the sufficiency classification proposed by Jones et al. (1991). Although the Kexc content in the soil is generally sufficient (with 24% being low in the lower layer, i.e., 25-50 cm), the fact that 48% of the plant leaves are deficient in K could be attributed to the lower Kexc content in the deeper soil layers compared to the surface layer, as well as the very high Caexc content in the soils. Kuzin and Solovchenko (2021) reported that imbalances in soil K/Ca can lead to physiological disorders in apples. For this reason, it may be recommended to apply K-containing fertilizers to a soil depth of 15-20 cm and to apply K-fertilizers to soils containing less K than approximately 600-700 kg K2O ha-1. Calcium levels in the leaf samples from the study area, according to Jones et al. (1991), are classified as deficient in 33% of the cases, adequate in 47%, and excessive in 20%. The deficiency of Ca in the leaf samples can be attributed to the high temperatures during the sampling period in July and the plant's inability to meet its water needs, which in turn reduces Ca uptake. Balota (2014) reported that plants can exhibit Ca deficiency even when soil Ca is adequate in regions with low soil moisture. Therefore, it is suggested to apply $Ca(NO_3)_2$ foliar sprays during the growing season to address Ca deficiency in apples (Genç, 1998). For Mg, Fe, and Cu no deficiencies were observed in the leaf samples according to Jones et al. (1991). The active iron content in the apple leaves ranges from 19.2 to 43.4 mg kg^{-1}, with an average of 29.7 mg kg^{-1}. Manganese levels in the apple leaves range from 11.5 to 123.3 mg kg^{-1}. According to Jones et al. (1991), Mn deficiency was found in 9.3% of the samples in the study area.The B content in the leaf samples showed deficiency in 80% of the cases according to Jones et al. (1991). The B deficiency in apple trees affects fruit set and is directly related to yield (Dong et al., 1997). The B deficiency in apples can lead to corky core disease and physiological disorders in the fruit (Turan and Horuz, 2012). Therefore, it is essential to include B in the fertilization program for the region.

CONCLUSION

The obtained data indicate that the soils are generally slightly alkaline (%84). The soils are lime and excessively lime. No deficiencies of Ca, Mg, or Cu were observed in the soils. However, Kexc deficiency is present in 16% of the soils, and the BA content is inadequate in all soils. Leaf analyses from apple trees reveal that all the leaves have N deficiency, while P levels are adequate. Deficiencies were observed in 48% of the leaves for K, 33% for Ca, 9.3% for Mn, 21.3% for Zn, and 80% for B. Significant differences were found between the physical and chemical properties of the soils and the available macro and micro-element contents at soil depths of 0-25 cm and 25-50 cm. Since the active rooting depth for the plants is 25-50 cm, it is recommended to apply P and micro-element-containing base fertilizers to this depth (15-20 cm). As soil pH values above 7.5 and the presence of high levels of lime can negatively impact the uptake of Zn and B as well as other micro-elements, the application of OM and elemental sulfur is advised to mitigate these issues.

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Effects of Maize Harvest Residue Compost at Different Maturity Levels and Maize Stubble on Soil Aggregation Properties

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ABSTRACT

The physical properties of agricultural soils are adversely affected by excessive and unregulated use. The application of organic amendments is crucial in improving the degraded soil structure. This study was conducted under pot experiment in a randomized plot design, for to determine on effects of maize straw compost at different maturity on soil aggregate stability (AS) and mean weight diameter (MWD). Five different treatments were applied to soil samples: raw maize straw (MS), and maize compost matured for 15 (CO15), 30 (CO30), 45 (CO45), and 60 (CO60) days, at doses of 0.5%, 1%, and 2% by weight, followed by a 60-day incubation period. At the end of the 60-day incubation, AS and MWD were measured. Results indicated that, at the end of the incubation period, the AS value, which was determined as 12.35% in the control, reached its highest level with the 2% dose of MS application, showing an increase of 28.58% to 15.88%. Similarly, the MWD value, initially measured at 0.046 mm in the control, increased to 0.099 mm with %2 dose of MS application. Both physical quality parameters were significantly influenced by the amendments; however, due to the high carbon content and fine particle size of the maize straw, it has the most pronounced effect on improving soil properties.

Keywords: Compost maturation time, soil aggregation, soil physical quality

INTRODUCTION

The intensification of agricultural activities has resulted in soils being subjected to excessive processing and utilisation, leading to structural deterioration. This consequently jeopardises the future sustainability of soil utilisation. It has been established through research that soils with a low organic matter content typically exhibit reduced yield capacities. The deterioration of soil physical properties is exacerbated by the combination of low organic matter content and unconscious and unsuitable soil processing activities. Furthermore, the regular processing of soils on an annual basis and the uninterrupted pursuit of agricultural activities have been identified as detrimental to soil health, which in turn results in a reduction in yield potential in production (Şeker et al., 2022). The utilisation of organic carbon-based substances for the enhancement of these soils, which are deficient in terms of physical properties, has been a growing phenomenon in recent years (Manirakiza et al., 2021; Negiş and Şeker, 2021). Concurrently, the application of organic amendments has been demonstrated to enhance soil microbial biomass and improve soil physical properties (Öztürk et al., 2010; Gümüş and Şeker, 2017). The organic matter content of our country's soils has been elucidated by numerous studies (Şeker et al., 2017). It is imperative that this ameliorative maize stubble material, which has been developed for our country's soils, which typically exhibit low organic matter content, be incorporated into soil management practices. Furthermore, the absence of organic matter can lead to adverse effects on soil physical properties, thereby increasing the risk of soil degradation through repeated use. The future management of these stubble materials will ensure a reduction in the use of fertilisers in agriculture and the protection of soil fertility. The increasing intensive processing practices and the use of soils beyond their capacity are causing soils to become barren, which is one of the most significant issues facing our soils in the future.

It is therefore evident that organic-based materials assume a significant role at this juncture. Accordingly, the objective of this study is to determine which compost maturity level is more beneficial for soil health by utilising maize stubble compost at varying maturity stages (15, 30, 45 and 60 days). The efficacy of three different doses (0.5%, 1%, 2%) of the composts at different maturity levels was also evaluated in terms of their impact on the quality characteristics of the trial soil. Additionally, to address the question of whether an effect is observed with direct application without composting the stubble, three doses of ground maize stubble were included in the trial, in addition to different doses of compost at different maturity levels. Following the applications, an investigation was conducted into the improvement of the quality status of a soil with low physical quality. The results of this investigation, together with the findings of the necessary analyses and evaluations, have led to the development of suggestions for field studies and practical use.

MATERIALS AND METHODS

Material

The soil sample used in the study was taken from an agricultural field in Konya-Çumra district. The organic materials determined to be used in this study are direct application of maize straw, (MS) and maize stubble compost (MC) at certain maturity levels of maize stubble. For the direct use of maize stubble to be used in the experiment, the stubble material was ground to increase the surface area and to ensure rapid decomposition and disintegration. During the composting period, samples were taken at the end of the 15, 30 and 45 days of the composting process and the total composting process was completed in 60 days without any nutrient loss.

Method

The study was carried out in a total of 64 pots, and the experiment was set up with 4 replications from each application, with 5 kg of oven-dry soil in each pot. In the experiment, compost at the maturity level of 15-30-45-60 days and ground maize stubble were used in the control, 0.5, 1 and 2 doses. After adding the determined doses of materials to the soil samples placed in pots, they were mixed well, then moistened to 80% of the field capacity level and left for a 60-day incubation period. At the end of the experiment, aggregate stability (AS) and average weighted diameter (MWD) analyses were performed on the soil samples. Only for the average weighted diameter analysis, at the end of the 60th day, some of the samples were separated for analysis by passing through a 4-mm sieve and the remaining samples were sieved through a 2-mm sieve and aggregate stability analysis was performed on these samples.

RESULTS

Properties of the Soil Used in the Study

The results of the physical and chemical analyses conducted on the soil sample utilized in the study are presented in Table 1. Accordingly, the soil can be classified as a sandy clay (SC) according to the texture classification system. The aggregate stability value is 12.27%, and the average weighted diameter is 0.046 mm. Upon examination of the chemical properties of the experimental soil, it was determined that the pH value is 9.02, indicating a strongly alkaline nature (>8.5) and that there is no evidence of salinity issues (Richards, 1954). The organic matter content of the soil sample is in the very low class, at less than 1%, while the total nitrogen content is in the low class, at 0.08% (FAO, 1990). The lime content of the soil was determined to be 15.65%, indicating a very calcareous classification (Ülgen and Yurtsever, 1974).

Table 1. General soil properties

Properties	Unit %	Value
	Sand	45.23
Texture	Silt	11.85
	Clay	42.92
Texture Class	-	Sandy Clay (SC)
AS	%	12.27
MWD	mm	0.046
FC	%	22.19
pH	-	9.02
EC	mS cm-1	316
CaCO3	%	15.65
OM	%	0.58

Change in Aggregate Stability

The impact of the applications on aggregate stability was determined to be statistically significant ($p < 0.05$). The data pertaining to the results are presented in Figure 1.

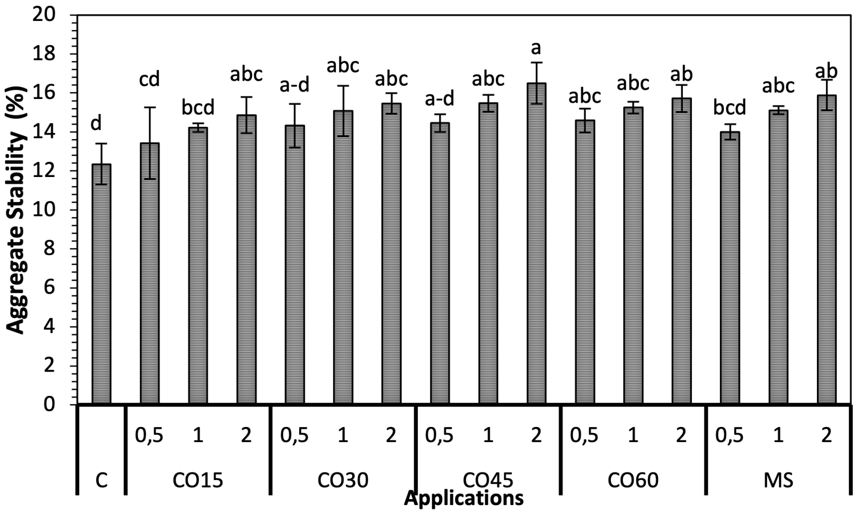

Figure 1. Change in aggregate stability with applications

The AS value was found to be 12.35% in the control sample, while the highest CO452 application resulted in a value of 16.49%. While CO452, CO602 and MS2 were found to increase the AS value in a statistically significant manner in comparison to the control sample, the effect of the low doses of the other applications was found to be insignificant in comparison to the control.

Change in Average Weighted Diameter

The impact of compost and ground maize stubble application on average weighted diameter (MWD) is illustrated in Figure 2. The observed differences in MWD values with the applications were found to be statistically significant ($p < 0.05$). The highest MWD value was observed in MS2, reaching 0.099 mm, which represents an increase of 115.22% compared to the control. In contrast, CO152 resulted in an increase of 47.83% compared to the control, while the effects of the other applications were found to be statistically insignificant. The application of 0.5% doses of all maturity levels of compost resulted in an increase in comparison to the control, although no statistically significant difference was observed between the treatments ($p > 0.05$). The lowest mean weighted diameter (MWD) value was observed in the control application, with a value of 0.046 mm.

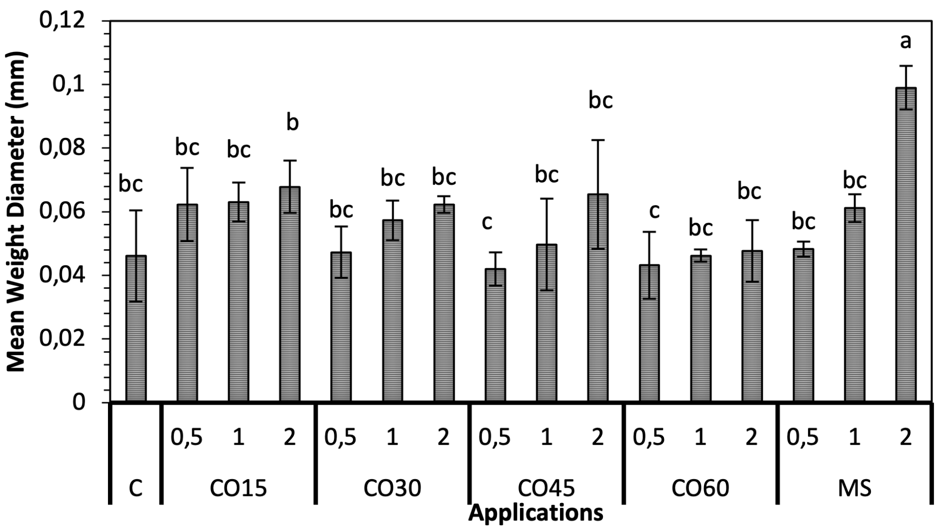

Figure 2. Change in average weighted diameter with applications

DISCUSSION

Soil particles with favorable aggregation properties exhibit enhanced binding capabilities, resulting in elevated folliculation. However, the compositions that cement and strengthen the bonds between soil particles are present in lower quantities in soils with weaker aggregation properties. This results in lower folliculation and a higher tendency for dispersion. Consequently, numerous studies, including the present one, have demonstrated that AS values, which are among the most crucial indicators of structural development in our soils, are partially influenced by these organic matter applications. The incorporation of maize stubble through direct grinding and composting has been shown to enhance soil structure (Olsen et al., 1970; Sommerfeldt and Chang, 1985). The addition of organic matter has been demonstrated to increase soil aggregation and, consequently, to encourage soil structural development (Negiş, 2024). Similarly, the markedly low MWD values can be attributed to the low organic matter content of the study soil and the high exchangeable sodium percentage (ESP). Nevertheless, some of the organic matter applications resulted in a notable increase in MWD value, although the desired levels were not attained. The limitation of both parameters was attributed to the high concentration of exchangeable sodium in the study soil and the prevalence of dispersion conditions in the environment (Ben-Hur et al., 1985).

CONCLUSION

Upon examination of the effects of maize stubble compost and ground maize stubble applications, selected as the application material in the study on the quality properties of the soils, it was found that there was an increasing effect on AS and MWD from the physical quality properties. This indicates that the physical characteristics of the soil have improved. The applications of maize stubble and compost at 45 and 60 days were observed to be particularly efficacious, with a general improvement in soil quality observed across all maturity levels. The amendment materials were effective in both physical quality parameters; however, the application of maize stubble was particularly impactful due to the high carbon and organic matter content of maize stubble and the fact that it was finely ground. The degree of effect was notably high. Improvements were observed in both parameters, although the effects were limited. This was due to the fact that the chemical structure of the soil had been compromised, and it was established that the desired effect could not be achieved unless the chemical structure was improved, regardless of the quantity of organic material added for the purpose of developing the physical structure.

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Comparison of Two Different Soil Quality Approaches for Assessment of Agricultural Soils

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ABSTRACT

Sustainable agriculture is a form of farming that aims to meet the food and agricultural product needs of the present generation without compromising the ability of future generations to meet their own needs. This approach prioritizes the conservation of natural resources, the reduction of environmental degradation, and the maintenance of economically viable agricultural activities. One of the fundamental tenets of sustainable agriculture is the conservation and enhancement of soil quality. Soil quality is a complex phenomenon comprising a range of physical, chemical, and biological properties that directly influence agricultural productivity and support ecosystem services. The objective of this study is to determine the quality of agricultural lands in the Zile district of Tokat using different soil quality methods and to compare these models. A total of 175 soil samples were collected from the study area and subjected to Principal Components Analysis (PCA) to create a Minimum Data Set (MDS) comprising 10 parameters. Two cumulative quality indices, the Integrated Quality Index (IQI) and the Nemero Quality Index (NQI), were then applied to the MDS to determine soil quality. The results were used to create distribution maps of the area, with quality scores adjusted to five classes using the Natural Breaks (Jenks) method. Upon examination of the maps, it was observed that the two different soil quality methods applied to the same study area revealed the quality status of the area with high similarity.

Keywords: Soil quality, Nemero quality index, Integreted quality index

INTRODUCTION

Soil quality is of crucial importance with regard to the sustainability of agriculture and the health of ecosystems. The productivity of soil is contingent upon a multitude of factors, including its physical, chemical, and biological properties, as well as its capacity to retain water, facilitate nutrient cycling, and sustain microbial activity. Soil quality is a direct parameter influencing plant growth and ecosystem health (Pacci and Dengiz., 2021). Soils of high quality are able to retain water and nutrients more effectively, facilitate the development of roots, and are more resilient to erosion. A decline in soil quality can result in a reduction in agricultural productivity and the subsequent deterioration of the environment (Lal, 2001; Karlen et al., 1997). Consequently, it is imperative to implement a continuous monitoring and assessment program for soil quality.

It is of paramount importance to assess soil quality in an objective manner, as this is crucial for agricultural productivity, environmental sustainability, and human health. Metrics such as the Nemero Quality Index (NQI) and the Integrated Quality Index (IQI) have been developed as significant tools for providing a comprehensive evaluation of soil health. The NQI is a criterion used to assess soil quality, incorporating a combination of various physical, chemical, and biological properties. This index is regarded as a valuable instrument for elucidating its influence on soil productivity and health (Smith, 2010). On the other hand, IQI integrates various soil quality indicators, similar to NQI, to provide a more comprehensive assessment. By considering physical, chemical, and biological parameters, IQI offers detailed information about the overall condition of soil quality and plays a crucial role in making strategic soil management decisions (Samaei et al., 2022).

The use of modern analytical methods and technologies to assess soil quality is crucial for optimizing agricultural production and minimizing environmental impacts. In this context, advanced analytical techniques such as Principal Component Analysis (PCA) and Geographic Information Systems (GIS) are important tools for assessing soil quality and mapping its spatial distribution.

Principal Component Analysis (PCA) identifies the principal components in multivariate data sets and creates new variables that explain most of the variance in the data set. This method is used to understand the relationships among soil quality indicators and to identify the most important parameters. PCA is particularly useful in analyzing complex and large data sets by reducing the dimensionality of the data to obtain more meaningful results (Jolliffe, 2002). PCA is a linear method of analysis. Algebraically, principal components are expressed as linear combinations of p random variables, while geometrically, these linear combinations define a new coordinate system by rotating the original axes. The new axes represent the directions of greatest variability (Johnson and

Wichern, 1982). Regardless of the method used to extract factors or components, similar results are obtained with a good data set, and different rotation methods tend to produce similar results when correlations are quite strong (Tabachnick and Fidell, 2001).

Geographic Information System (GIS) is a powerful tool for spatial analysis and visualization of soil data. Using GIS, it is possible to map and analyze the spatial distribution of soil quality indicators. In the study by Shi et al. (2019), GIS-based analyses were used to investigate the spatial variation of soil quality and provide strategic recommendations for agricultural management. GIS-based analysis is crucial for applications such as agricultural land management, erosion risk assessment, and soil productivity improvement (Burrough and McDonnell, 1998).

In this study, a total of 175 soil samples were collected from the study area in Zile district of Tokat province with the aim of determining soil quality. These samples were subjected to Principal Component Analysis (PCA) to create a minimum data set (MDS) consisting of 10 parameters. Subsequently, two cumulative quality indices, the Integrated Quality Index (IQI) and the Nemero Quality Index (NQI), were applied to the MDS to determine soil quality. Using the Natural Breaks (Jenks) method, the quality scores were classified into five classes and distribution maps of the region were created based on these scores.

MATERIAL AND METHOD

Description of study area

Tokat province is located between 36° 00'- 36° 42' eastern longitudes and 39° 52'- 40° 55' northern latitudes in terms of its geographical location. It is bordered by Samsun to the north, Ordu to the northeast, Sivas to the south and southeast, Yozgat to the southwest, and Amasya to the west. The study area is the Zile Plain, which is situated within the boundaries of Tokat province in the Central Black Sea Region, 70 km west of the provincial center. It is one of the most important plains in the region due to its suitability for intensive agricultural activities, which are enabled by the semi-arid climate (Figure 1).

For the study area, based on meteorological data for many years, the annual average temperature is 12.6°C, the annual average precipitation is 431.4 mm, and the annual average evaporation value is 726.3 mm. According to the Newhall model, when soil and temperature regimes are calculated, the soil moisture regime is determined as xeric, and the temperature regime is determined as mesic. Soil samples were collected from the study area in the year 2020. The area was divided into grids of 200m x 200m, and using the global positioning system (GPS), the locations of soil samples were identified. Then, 175 disturbed and undisturbed soil samples from the surface (0-30 cm) were collected from each corner of each grid. Subsequently, the samples were brought to the laboratory. After air-drying the soil samples, they were pulverized using a wooden mallet and sieved through a 2 mm sieve to prepare them for analysis. It was analyzed according to the methods outlined in Table 1.

Figure 1. Description on the study area

Table 1. soil analysis methods

Parameters	Unit	Protocol	Reference
Aggregate stability (AS)	%	Wet sieving	Kemper and Rosenau (1986)
Dispersion ratio (DR)	%	DR= (a/b)* 100	Lal and Elliot (1994)
Erodibility ratio (ER)	%	ER= (a/b)*(A/c)*100	Lal and Elliot (1994)
Clay ratio (CR)	%	CR=(100-c)/c	Bouyoucos (1935)
Clay, Silt and Sand)	%	hydrometer method	Bouyoucos (1951)
Organic Carbon (OC)	%	Walkley-Black	Nelson and Sommers (1982)
Total N	%	Kjeldahl	Bremner and Mulvaney (1982)
Bulk Density	g cm-3	Undisturbed soil sample	Burt, 2014

a is the percentage of silt plus clay in suspension, b is the percentage of silt plus clay dispersed with chemical agent, A is the field capacity, c is the percentage of clay dispersed with chemical agent.

Creating a minimum data set using the Principal Component Analysis (PCA) method

The soil quality index within the study area was determined through the application of Principal Component Analysis (PCA) to 30 indicators. PCA facilitated the assessment of soil quality and resulted in the creation of a minimum data set (MDS) to provide a comprehensive overview of the study area. In the research, factor analysis will be conducted to consider the relationships among the 30 soil properties. The objective of the Principal Component Analysis is to establish the factors, which in turn will facilitate the formation of the minimum data set. Factor loadings represent the straightforward correlations between soil properties and each factor. Eigenvalues indicate the proportion of variance explained by each factor. In the study, factors with eigenvalues greater than one will be selected to explain the total variance. That is, groups with eigenvalues equal to or greater than 1 will be accepted as factors, with a critical factor loading set at 0.5 (Andrews et al., 2002; Wander and Bollero, 1999). For each factor, the soil variables with the highest factor loadings will be identified as the best indicators of changes in soil quality. The highest factor loading will have absolute values within 10% (Govaerts et al., 2006; Sharma et al., 2005; Nabiollahi et al., 2017). The factors selected based on the eigenvalue statistic will then undergo a varimax rotation process. The objective of this method is to maximize the relationship between dependent soil properties by redistributing the variance of each factor.

Weighting and scoring soil quality parameters using the standard scoring function (SSF)

To determine the score of variables with the most desired value in terms of soil quality, a value of 1 was assigned to the range with the highest quality value, and a value of 0.1 was assigned to the range with the lowest quality value (Kalambukattu et al., 2018). For the purpose of weighting the effective indicators in both the TDS and MDS, the communalities of each indicator were calculated through factor analysis using SPSS software (Cherubin et al., 2016). For this purpose, the ratio of the communality value of each property to the sum of the communality values of all indicators in each set (TDS and MDS) (Equation 3) was considered as the weight of each indicator (Biswas et al., 2017). Finally, by combining the scores and weights of different indicators, the Integrated Quality Index (IQI) and Nemero Quality Index (NQI) were calculated using Equations (4) and (5).

$$Weighting\ factor = (Communality)/(Sum of communalities) \quad (3)$$

$$IQI = \sum_{i=1}^{n} NiWi \quad (4)$$

Where, n is the number of factors, Ni is the score value or score assigned to each factor, Wi is the weight of each factor.

$$NQI = \sqrt{P_{ave}^2 + P_{min}^2/2} \times n - 1/n \quad (5)$$

Where, Pave is the average scores of the selected factors in each site, Pmin is the minimum scores of the selected factors in each site and n is the number of factors.

Soil properties have different scales and units; therefore, it is necessary to convert soil factors into unitless scores ranging from zero to one (Omer et al., 2020). To achieve this, data ranking or standardization was employed using standard scoring functions (SSF), assigning scores ranging from 0 to 1 (Andrews et al., 2002a; Andrews et al., 2002b). According to this method, different soil properties follow three functions (Karlen et al., 2014):

1. The "Optimum Range" function (OR), where scores are distributed using either of the previous functions based on whether the value of this index is more or less than the optimum range (e.g., soil reaction: pH).
2. The "More is Better" function (MB), used for soil indicators that improve soil quality (e.g., organic carbon: OC).
3. The "Less is Better" function (LB), used for soil indicators that reduce soil quality (e.g., bulk density: BD).

The equations used for scoring soil properties between 0.1 and 1.0, "less is better" (Equation 6) and "more is better" (Equation 7), are as follows:

$$f\,(x) = \begin{cases} 0.1 & x \geq L \\ 1 - 0.9 \times \frac{x-L}{U-L} + 1 & L \leq x \leq U \\ 1.0 & x \leq U \end{cases} \quad (6)$$

$$f\,(x) = \begin{cases} 0.1 & x \geq L \\ 0.9 \times \frac{x-L}{U-L} + 0.1 & L \leq x \leq U \\ 1.0 & x \leq U \end{cases} \quad (7)$$

RESULTS AND DISCUSSION

Principal Component Analysis (PCA) was applied to the total data set in order to create a minimum data set. The eigenvalues and the number of principal components explaining the variance are presented in Table 1. In determining the parameters that can be included in the minimum data set, the component loadings determined by PCA, the sums of correlation loadings, and correlation analysis methods between the data were considered. The results of the PCA indicated that eight principal components with eigenvalues greater than one collectively explained 75.431% of the variance (Table 2). The PCA analysis resulted in the creation of a minimum data set comprising 10 of the

30 indicators considered in the total data set. The first principal component accounted for 25.349% of the variance. The remaining components explained variances of 16.830%, 10.506%, 6.107%, 5.266%, 4.213%, 3.786%, and 3.373%, respectively.

In selecting features for the principal components, the feature with the highest loading was chosen, and features with weights within 10% of that loading were considered. Other features were subsequently excluded from the data set. Furthermore, among the features exhibiting high correlation within the data set, selections were made to ensure minimal redundancy (Alaboz, 2020).

Table 2. Principal components and distributions of parameters

	Principal Components								
	PC-1	PC-2	PC-3	PC-4	PC-5	PC-6	PC-7	PC-8	Toplam Korelasyon Yükleri
Total	7.605	5.049	3.152	1.832	1.580	1.264	1.136	1.012	
Variance %	25.349	16.83	10.506	6.107	5.266	4.213	3.786	3.373	
Cumulative %	25.349	42.180	52.686	58.793	64.058	68.272	72.058	75.431	
DR	0.712	0.010	0.034	0.305	0.078	0.108	0.106	0.024	8.772
AS %	0.382	0.334	0.099	0.538	0.185	0.270	0.043	0.042	6.613
Sand	0.867	0.396	0.124	0.075	0.177	0.051	0.037	0.024	10.357
Clay	0.864	0.409	0.024	0.105	0.049	0.196	0.003	0.006	10.299
Silt	0.102	0.013	0.347	0.415	0.529	0.564	0.081	0.044	4.108
BD	0.828	0.110	0.175	0.151	0.200	0.004	0.255	0.037	10.444
FC	0.938	0.278	0.033	0.073	0.018	0.109	0.002	0.034	10.748
WP	0.909	0.314	0.034	0.113	0.038	0.180	0.021	0.016	10.588
AWC	0.801	0.030	0.331	0.132	0.269	0.247	0.084	0.108	10.147
HC mm/h	0.766	0.252	0.254	0.056	0.012	0.038	0.231	0.156	8.946
SAR	0.284	0.278	0.782	0.151	0.183	0.154	0.058	0.094	6.403
EC(dS/m)	0.480	0.176	0.308	0.147	0.343	0.169	0.071	0.016	6.966
pH	0.271	0.736	0.268	0.211	0.077	0.020	0.081	0.001	8.289
CaCO3	0.162	0.036	0.408	0.452	0.132	0.413	0.057	0.270	4.721

OC	0.387	0.688	0.257	0.215	0.166	0.201	0.334	0.052	7.889
OM	0.387	0.688	0.257	0.215	0.166	0.201	0.334	0.052	7.889
CEC	0.043	0.170	0.193	0.283	0.186	0.208	0.375	0.562	3.449
Β-Glikozidaz	0.414	0.474	0.351	0.037	0.115	0.048	0.364	0.114	7.655
MBC	0.234	0.596	0.220	0.137	0.169	0.050	0.299	0.129	6.477
N %	0.174	0.782	0.139	0.018	0.139	0.084	0.142	0.096	7,848
P ppm	0.229	0.206	0.191	0.255	0.196	0.150	0.461	0.147	4.513
K ppm	0.455	0.069	0.436	0.414	0.243	0.005	0.088	0.204	7.685
Mn ppm	0.239	0.477	0.094	0.206	0.426	0.117	0.106	0.258	6.056
Cu ppm	0.405	0.158	0.213	0.564	0.175	0.151	0.075	0.110	6.215
Fe ppm	0.020	0.473	0.178	0.073	0.292	0.215	0.029	0.496	5.269
Zn ppm	0.148	0.556	0.241	0.143	0.406	0.184	0.202	0.132	6.255
Na ppm	0.315	0.360	0.703	0.208	0.060	0.220	0.081	0.150	6.882
Mg ppm	0.174	0.549	0.340	0.169	0.274	0.068	0.189	0.259	6.941
Ca ppm	0.471	0.387	0.037	0.112	0.380	0.318	0.015	0.106	7.173
B ppm	0.045	0.359	0.714	0.081	0.069	0.247	0.210	0.140	5.371

DR: Dispersion ratio, AS: Aggregate stability, BD: Bulk density, FC: Field capacity, WP: Wilting Point, AWC: Available water content, HC: Hydraulic conductivity, SAR: Sodium adsorption ratio, EC: Electrical conductivity, OC: Organic carbon, OM: Organic matter, CEC: Cation exchange capacity, MBC: Microbial biomass carbon

Determining the weights of parameters in the minimum data set

The contribution values of each attribute (Communality) resulting from factor analysis (FA) in MDS in Table 3. Weight the effective features were calculated by Equation (1). The effectiveness of each feature in soil quality models depends on the weight assigned to that feature. In other words, higher weights in the MDS have a greater impact on the soil quality model and with decreasing weight, this effect decreases (Mukherjee et al., 2014). The results of weight calculation in MDS showed that the field capacity parameter had the highest weight and the active carbon and cation exchange capacity parameter had the lowest weight.

Table 3. Estimated communality and weight values of each soil quality indicator in TDS and MDS in pasture land use.

Parameter	Communality	Weight
AS %	0.750	0.1136
Silt	0.533	0.0806
FC	0.806	0.1220
pH	0.779	0.1179
CEC	0.396	0.0599
N %	0.658	0.0996
P ppm	0.543	0.0822
Cu ppm	0.669	0.1012
Na ppm	0.805	0.1219
B ppm	0.666	0.1007

Soil quality distribution maps

The distribution maps and classification graphs created from the obtained quality scores are shown in Figures 2 and 3. In the IQI map, soil quality is classified as follows: very low between 0.396 - 0.513, low between 0.513 - 0.548, moderate between 0.548 - 0.573, high between 0.573 - 0.605, and very high between 0.605 - 0.720. Upon examining the distribution map, areas of low quality are observed sporadically in the interior parts of the study area, with the lowest quality identified in the northeastern part. It is postulated that the low soil quality observed in these regions is a consequence of a complex interplay of factors. These include low organic matter and moisture content, in conjunction with high levels of sand, sodium, bulk density, and hydraulic conductivity. These factors collectively contribute to the deterioration of soil properties, including aggregate stability, structure stability, and microbial biomass carbon reduction. Overall, the majority of the study area is categorized as moderate to high quality. Bulk density is a parameter that determines the soil's density and the spaces between particles. A high bulk density can compress the soil structure and reduce water permeability, thereby negatively affecting aggregate stability (Six et al., 2000). Research indicates that low bulk density contributes to improved aggregate stability by promoting a more porous soil structure (Tisdall and Oades, 1982).

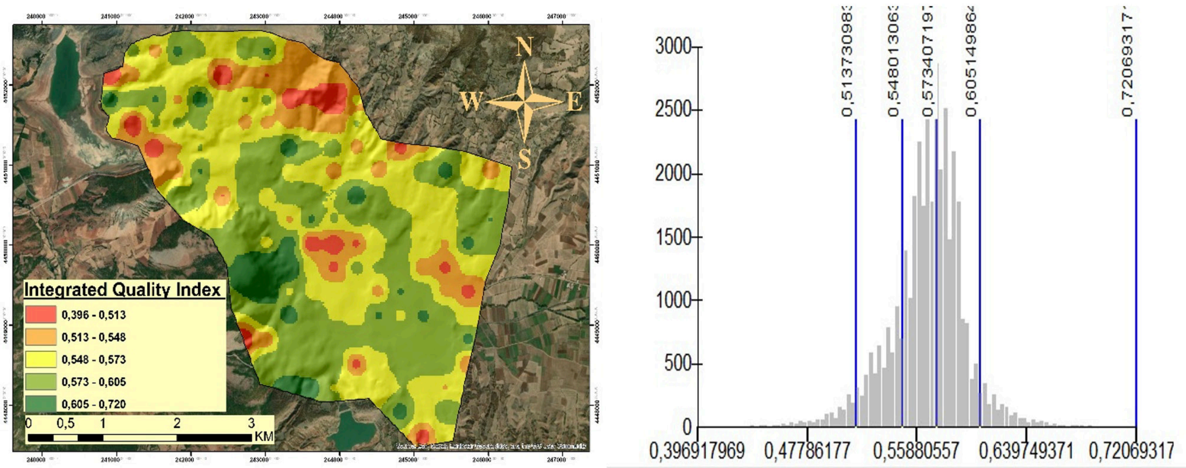

Figure 2. Integrated quality index distribution map and classification graph

It is evident that organic matter plays an indispensable role in enhancing various properties of soil. These include its physical, chemical and biological attributes. As the organic matter content increases, the connections between soil structures become stronger, thereby contributing to the formation of more stable aggregates. Furthermore, an increase in organic matter can enhance the soil's water retention capacity, which in turn contributes to the preservation of soil structure (Puget and Drinkwater, 2001; Saygın et al., 2023).

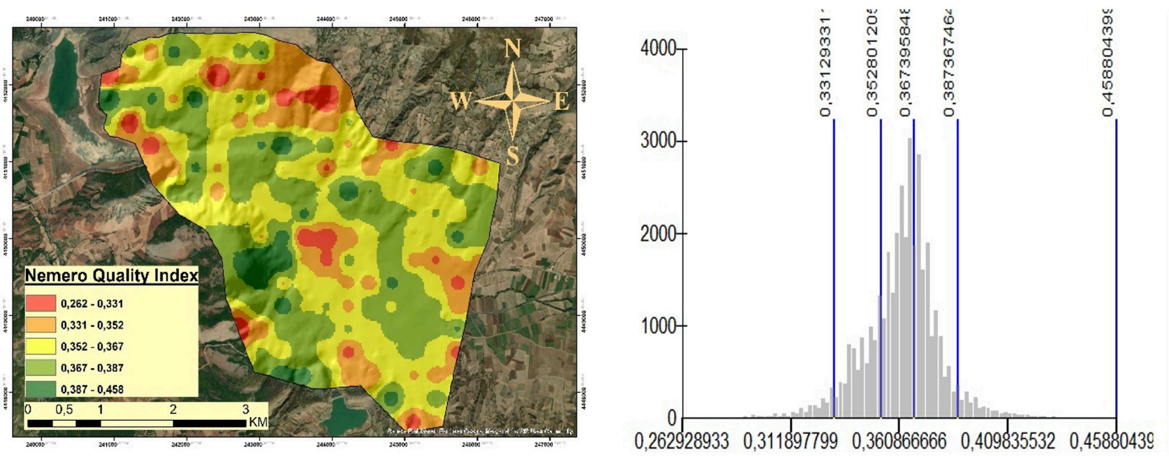

Figure 3. Nemero quality index distribution map and classification graph

In the NQI map, soil quality is classified as follows: very low between 0.262 - 0.331, low between 0.331 - 0.352, moderate between 0.352 - 0.367, high between 0.367 - 0.387, and very high between 0.387 - 0.458. Upon examining the distribution map, it is observed that although the quality value ranges differ between NQI and IQI distribution maps, the same areas exhibit soil qualities in both high and low categories across the study area. This situation indicates that both methods can calculate soil quality in the study area in a parallel manner and accurately reflect the soil quality across the area.

CONCLUSION

The study was conducted in the Zile district of Tokat, a region characterized by a plain topography. The objective was to ascertain the quality of the soil through the application of two distinct methodologies, with the subsequent generation of distribution maps. Upon examination of the results, it was found that both models depict the soil quality of the study area in a similar manner. The soil quality of the study area is generally classified as moderate to high, with areas of low quality observed in the northeastern and interior parts on an occasional basis. To enhance soil quality in these regions, it is advised to implement less intensive agricultural practices and incorporate organic matter into the soil.

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The Effect of Chicken Litter Ash and Rock Phosphate Applications on The Growth of Einkorn Wheat (Triticum monococcum ssp. monococcum) and Some Soil Properties

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ABSTRACT

This study was carried out to determine the effects of rock phosphate and chicken litter ash applications on the growth criteria of einkorn wheat, plant phosphorus content and some soil properties of the growing environment. Plant fresh and dry weights, plant height and number of tillers were determined and plant phosphorus analysis was performed on the harvested plants. Plant fresh and dry weights, plant height, number of tillers and plant phosphorus content of the harvested plants were determined and pH, lime, salt and available phosphorus were analyzed in the growing environment. As a result of the statistical analysis applied to the data obtained, at 2.5% dose of chicken litter ash applications, the highest plant height (38.3 cm), plant fresh weight (0.4735 g), plant dry weight (0.0999 g), number of tillers (15 units) and plant phosphorus content (3339 mg k-1) were obtained. The highest values in terms of pH, salt, lime and available phosphorus in the growing environment were determined as 8.90, 1363 µS cm-1, 4.87% and 172 mg kg-1, respectively, in 5% chicken litter ash applications. As a result, it was determined that the combined application of rock phosphate and chicken litter ash did not have a significant effect on plant development and soil properties, and that chicken litter ash applications had a significant effect on both development criteria and soil properties. As a result, it was determined that the combined application of rock phosphate and chicken litter ash had no significant effect on plant development and soil properties, and that chicken litter ash applications had a significant effect on both development criteria and soil properties. It was determined that 2.5% dose of chicken litter ash application was applicable in terms of the examined criteria.

Keywords: Chicken litter ash, rock phosphate, einkorn wheat, soil properties

INTRODUCTION

Our country's phosphate reserves are 300-400 million tons and are generally located in the Southeastern Anatolia region, 70 million tons of which are processable. Due to low phosphorus grade, the desired production level cannot be achieved and accordingly, imports are resorted to in order to meet the country's demand (Demir and Yalçın, 2004). Only 10-30% of the phosphorus fertilizers given with chemical fertilizers are taken up by plants (Mclaughlin et al., 1988), the rest is either fixed or washed with rain or irrigation water and may mix with groundwater or surface water and cause their pollution (Shigaki et al., 2006). Producers attach importance to activities to reduce the use of chemical fertilizers that cause environmental pollution (Te-Hsiu, 1999). The fact that the phosphorus it contains, which is an important factor limiting the use of rock phosphate used for this purpose, is difficult to be directly absorbed by plants, has created a need for alternative applications. These are applied to agricultural areas by treating rock phosphate with sulfuric acid (Osman, 2015), application with phosphate-dissolving bacteria (Arif et al., 2018), and application after incubation with various organic materials (Ditta et al., 2018). In order to meet the demand for white meat consumption brought about by the increase in the world population, more poultry houses are established and as a result, excessive chicken litter waste pollution is in question. If it is assumed that an average poultry produces 22 kg/year of feces, it is reported that more than 10 million tons of chicken manure will be produced in our country in a year, which is equivalent to around 1 million tons of power plant ash. Ash production from thermal power plants burning chicken litter waste in our country will reach 600 tons/day by the end of 2022 (Çöteli and Karahan, 2023). Bolu province, which meets almost 8.7% of our country's white meat needs and 2.3% of its egg needs (Anonymous, 2024), is faced with the problem of chicken litter waste in this context. A few private entrepreneurs burn the chicken litter waste generated in Bolu province to obtain electrical energy using the complete combustion or pyrolysis method, and as a result, chicken litter ash and chicken litter biochar are released. The evaluation of this waste ash and biochar is carried out in several ways. Its use in agricultural areas is one of them, and it is envisaged to be used especially as a source of phosphorus and potassium. Özdemir and Er (2018) found that the P2O5 (24.4%) and K2O (16.3%) values of chicken litter ash obtained as a result of burning chicken manure, were the highest compared to other organic wastes. Çöteli and Karahan (2023) reported that chicken waste ash was used in the production of organomineral fertilizers that are suitable for hazelnut areas in the Black Sea region and can be used in fruit and vegetable production. In this study, the effects of separate and combined applications of rock phosphate and chicken litter ash on some soil properties and available phosphorus content, as well as on the development and phosphorus content of the wheat plant were investigated.

MATERIAL AND METHOD

This study was carried out in the climate room of the Seed Science and Technology Department of Bolu Abant İzzet Baysal University between 10.11.2023 and 03.01.2024. In the experiment, rock phosphate (13% P2O5) obtained and ground from Mazıdağı district of Mardin province and chicken litter ash obtained from the enterprise established by a Company in Bolu province, where chicken litter waste is burned and converted into electrical energy, were used. The research was carried out in random plots, according to the factorial trial design, in pots containing 2 kg of soil, with 3 replications. Rock phosphate (RP) was weighed as 0, 2 g and 4 g P2O5 kg-1, and chicken litter ash (CLA) was used as 0%, 2.5% and 5%. Plant were grown in climate chamber conditions at 70% humidity, 16 hours day and 8 hours night, at 22±1°C. 20 Einkorn wheat (Triticum monococcum ssp. monococcum) seeds were planted in each pot. Distilled water was used for irrigation when needed from the beginning to the end of the experiment. Ammonium sulfate (21% N) fertilizer at a fixed dose of 200 mg N kg-1 was applied to the pots together with the seed planting. Plant fresh and dry weights, plant height, number of tillers were determined in the harvested plants, and phosphorus analysis was determined spectrophotometrically in the plant samples obtained by dry burning method as reported by Kacar and İnal (2008). Additionally, pH, lime, salt and available phosphorus analyzes in the growing media were performed according to Kacar (1994). Some analysis results of the rock phosphate and chicken bedding ash used in the experiment are given in Table 1.

Table 1. Some analysis results of the soil, CLA and RP used in the experiment

Source	pH	EC mS cm-1	Lime (%)	Texture	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Mn (%)	Zn (%)	Cu (%)
Soil	8.32	0.052	3.92	Loamy	0.027	0.248	0.564	0.326	0.007	0.011	0.003	0.017
CLA	13.42	15.17	-	-	3.85*	8.35*	17.0*	4.73*	0.559*	0.349*	0.059*	0.233*
RP	8.12	0.098	-	-	13.	0.77*	19.21*	0.41*	0.021*	0.121*	0.011*	0.012*

CLA, Chicken Litter Ash; RP, Rock Phosphate; *, total values

RESULTS

Effects of CLA and RP Applications on Some Properties of the Growing Media and Available Phosphorus Content

Chicken litter ash applications had a significant effect on soil pH, EC and available phosphorus content at the level of 0.1%, while it had an effect on the lime content at the level of 1% (Table 2). While the significant effect of rock phosphate applications on the soil properties was not determined, the chicken litter ash x rock phosphate interaction only had a 5% effect on pH.

Table 2. Variance analysis results regarding the effects of applications on soil properties

Variance	D.f.	pH MS		EC MS		Lime MS		Available P	
			F value		F value		F value	MS	F value
CLA	2	1.454	658.89***	7763	716.48***	3.6106	6.61**	92752	73.21***
RP	2	0.008	3.51 öd	762	0.07 öd	0,6050	1.10 öd	52.329	0.04 öd
CLAxRP	4	0.023	5.25 *	16495	0.08 öd	1,9111	1.74 öd	1213.7	0.47 öd

; 1%, *; Significant at 0.1% level, ns; non significant

Soil pH increased with the increase in chicken litter ash (CLA) doses (Table 3). A slight increase in pH was determined with rock phosphate applications, and the most significant increase was obtained in the application of 4 g P2O5 kg-1 compared to the control. Soil EC values showed significant changes only with CLA application.

Table 3. The means belonging the effects of applications on soil properties and Duncan lettering table

Treatments	pH	EC	Lime	Available P
		µS cm-1	%	mg kg-1
Chicken litter ash, %				
0	8.33 c	52.7 c	3.98 b	29 c
2.5	8.64 b	786.4 b	4.38 ab	95 b
5.0	8.90 a	1363 a	4.87 a	172 a
Rock phosphate, g P2O5 kg-1				
0	8.60 b	734	4.23	99
2	8.63 ab	740	4.41	99
4	8.65 a	727	4.59	97

a, b, c, d, e; There is no difference between the means shown with the same letter, Lsd ($p<0.05$); 4.22

The lime content of the experimental soil showed a significant change only with the CLA application, and the highest value was obtained in the 5% CLA application compared to the control. Available phosphorus content increased with CLA applications. Rock phosphate applications did not cause a statistically significant change in EC, lime and available phosphorus contents (Figure 1).

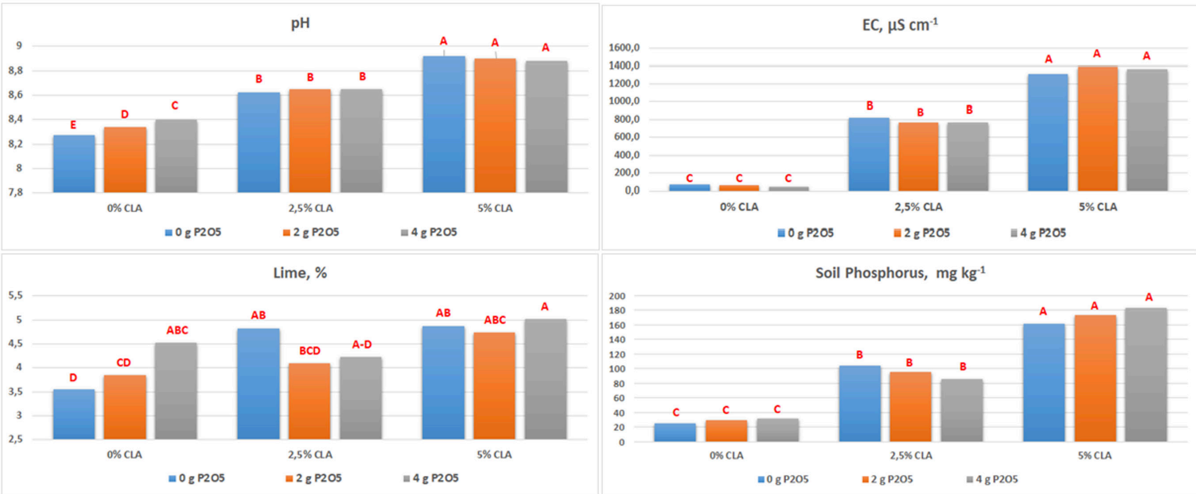

Figure 1. Effect of CLA x RP interaction on soil pH, EC, lime and soil phosphorus contents

Effects of CLA and RP Applications on Plant Growth and Phosphorus Content

CLA applications had a significant effect on plant height, plant fresh weight, plant dry weight, number of tillers and plant phosphorus content at 5% and 1% levels (Table 4). While rock phosphate applications had a 5% level effect on plant height, it was determined that its effect on other criteria was insignificant. CLA x RP interaction only had a 5% effect on plant height (Tables 4, 5).

Table 4. Variance analysis results of the effects of applications on plant growth criteria

Variance	D.f.	Plant height		PFW		PDW		Tillering	
		MS	F value	MS	F value	MS	F value	MS	F value
CLA	2	160.88	5.24*	0.2937	26.95**	0.00734	16.93**	1015.8	31.03**
RP	2	97.556	3.18 *	0.0095	0.87 öd	0.00015	0.36 öd	5.4074	0.16 öd
CLAxRP	4	239.56	3.90 *	0.0083	0.38 öd	0.00035	0.41 öd	39.481	0.60 öd

*; 5%, **; Significant at 0.1% level, ns; non significant, PFW; Plant Fresh Weight, PDW; Plant Dry Weight

Plant height, plant fresh weight, plant dry weight, number of tillers and phosphorus content were highest in the 2.5% CLA application compared to the control with 38.3 cm, 0.4735 g, 0.0999 g, 15.00 pieces and 3339 mg kg-1, respectively (Table 6). A generally decrease was determined in plant grow criteria by 5% CLA application.

Table 5. Variance analysis results belonging the effects of applications on plant phosphorus content

Variance	D.f.	Plant phosphorus content	
		MS	F value
CLA	2	3128421	8.02**
RP	2	955648	2.45 öd
CLAxRP	4	1363486	1.75 öd

**; Significant at 1% level, ns; non significant

Table 6. The means of plant growth criteria and phosphorus content of the applications and Duncan lettering table

Treatments	Plant P	PFW	PDW	Plant height	Tillering
	mg kg-1	g plant-1		cm	No.
Chicken litter ash, %					
0	2671 b	0.2325 b	0.0609 b	32.6 b	0.10 c
2.5	3339 a	0.4735 a	0.0999 a	38.3 a	15.00 a
5.0	2574 b	0.4266 a	0.0898 a	34.1 b	9.22 b
Rock phosphate, g P2O5 kg-1					
0	2693	0.3755	0.0852	33.1 b	7.48
2	2768	0.4014	0.0852	36.3 a	8.48
4	3124	0.3556	0.0801	35.6 ab	8.37

a, b, c, d, e; There is no difference between the averages shown with the same letter, PFW, Plant Fresh Weight; PDW, Plant Dry Weight

Rock phosphate application had a significant effect only on plant height among the development criteria, and the highest plant height was determined as 36.3 cm in the 2 g P2O5 kg-1 application compared to the control. The phosphorus content of plants growing in environments where CLA was not applied increased significantly with increasing RP applications (Figure 2).

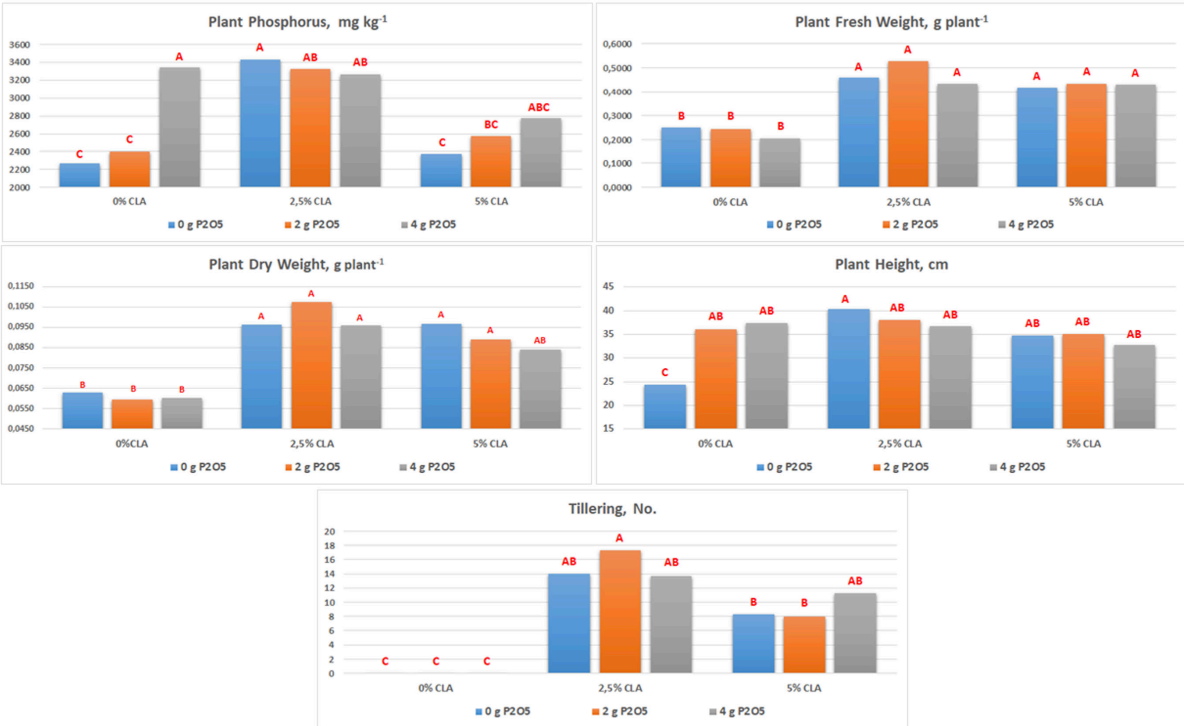

Figure 2. Effect of CLA x RP interaction on plant phosphorus, plant fresh weight, plant dry weight, plant height and tillering

DISCUSSION

Application of CLA in increasing doses caused significant increases in the pH and salt contents of the experimental soil. Similarly, Yusof et al. (2015) reported in their study that CLA and biochar applications caused significant increases in both pH and salt content of the soil. An increase in soil pH was determined with rock phosphate applications compared to the control. Similarly, Basak and Biswas (2016) reported in their study that CaCO3 contained in rock phosphate caused an increase in soil pH. It has been reported that chicken litter ash (CLA) can be used as a valuable material with the nutritional elements it contains (P, K, Ca, Mg, Na, S and microelements). It also contains silicate, calcite and apatite. It is reported in the literature that the potassium it contains is as effective as the potassium in chemical fertilizers (Ehlert, 2017; Bernal et al., 2024). Chicken litter ash is also considered as a source of phosphorus fertilizer (Cempa et al., 2022; Bernal et al., 2024). The phosphorus content both of the soil and the plant increased with CLA applications. On the other hand, the high alkalinity level of CLA causes the water-soluble form of the phosphorus it contains to be low (Acar, 2023). In our study, it was determined that the plant phosphorus content increased with 2.5% CLA application compared to the control, but it tended to decrease with 5% CLA application. This may be due to the increase in both salinity and pH values of the experimental soil. The increases in the lime content of the experimental soil with CLA applications compared to the control are due to the high CaO (60.1% on average) and Ca (17.0%) content of CLA. Materechera and Mkhabela (2002) reported in their study that the extractable calcium, magnesium and cation exchange capacity properties of the soil increased with ash application compared to the control. The decreases in the available phosphorus content with CLA applications are associated with the increase in soil pH, salt and lime contents with CLA applications. It is known that with the increase in soil pH, phosphorus turns into insoluble Ca3PO4 and its uptake by plants becomes difficult (Kacar, 1984). Considering the plant development criteria, it was determined that 2.5% CLA application had a more positive effect in terms of plant development criteria than 5% CLA application. CLA promotes the increases in plant development criteria with its nutrient content, but in high dose application it causes a regression due to the increases in the pH and EC of the growing medium. Codling et al. (2002), Pagliari et al. (2010) reported that poultry waste ash applications provided significant increases in plant development criteria. In combined applications of rock phosphate with CLA, increasing CLA doses caused a decrease in plant phosphorus content. It has been associated with the limitation of the availability of soil phosphorus as a result of the increase in pH and EC values and lime content of the growing medium caused by CLA applications. Makinde (2013) reported that the application of rock phosphate alone or together with barnyard manure increased plant growth criteria compared to the control. Similarly, Gweyi-Onyango et al. (2010) reported in their study that the application of rock phosphate together with nitrogenous fertilizers significantly increased plant growth compared to the control. In this study rock phosphate applications alone resulted in a significant increase in plant height relative to the control. In combined applications of rock phosphate with CLA, increasing CLA doses caused a decrease in plant phosphorus content. This situation has been associated with the limitation of the availability of soil phosphorus as a result of the increase in pH and EC values and lime content of the growing medium caused by CLA applications.

CONCLUCION

As a result, it is suggested that it would be more beneficial to apply rock phosphate and chicken litter ash separately, whereas if they are applied together, it is recommended to apply 2.5% chicken litter ash and 2 g P2O5 kg-1 doses. It is reported that the poorly soluble phosphorus content of CLA has a positive effect on the residual phosphorus content of growing media (Pagliariet al., 2010; Faridullah et al., 2013). The slow solubility of phosphorus in the structure of rock phosphate can make an important contribution to the nutrition of plants in some soil conditions (Khasawneh and Doll, 1979). This situation is especially prominent in soil conditions where phosphorus fixation is high. It has been reported that using rock phosphate with phosphate-solubilizing microorganisms (PSM) to increase its effectiveness (Reyaes et al., 2007; Sönmez, 2012; Nama et al., 2023) is beneficial.

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Investigation of Microplastics in Drainage Water: Berdan Plain - Tarsus

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ABSTRACT

This study examined the concentrations and distribution of microplastics (MPs) in drainage water samples collected from ten different drainage points in the Berdan Plain. A total of 97 MP particles and 1 mesoplastic particle were identified. The concentration of MPs ranged between 5 and 21 particles/liter. The highest concentration was recorded at the medium-density greenhouse area with 21 particles/liter. The average MP concentration was calculated to be approximately 9.7 particles/liter. Among the shapes of MPs, fibers were the most common, accounting for 69.1% of the total microplastics, followed by fragments at 30.9%. In terms of color distribution, white particles were found at a rate of 45.9%, while black particles were identified at 35.70%. The sizes of MPs varied between 0.042 mm and 1.827 mm. According to these data, the spread of MPs through drainage waters was analyzed, and it was determined that they were particularly concentrated in greenhouse areas. This study highlights the critical role of drainage water systems in the transfer of MPs from soils to aquatic environments, underscoring their importance in environmental pollution and reinforcing the need for advanced research into these pathways, particularly in relation to their potential to disseminate pollutants into larger water bodies.

Keywords: Microplastics, drainage water, plain, pollution

INTRODUCTION

Soils are threatened by various pollutants that are introduced through different pathways. Among these pollutants are MPs, referred to as “emerging contaminants”. Plastics are synthetic polymers widely used in daily human life for various purposes. Once these plastic materials enter soil or aquatic environments, they degrade into smaller MP particles. Microplastics are defined as fragmented plastic particles less than 5 mm in length (Cole et al., 2011). These MPs can have positive, negative, or neutral effects on the characteristics of the environment in which they are present (Souza Machado et al., 2018; Luo, 2022). Due to their size and type, they often persist in the environment for many years, making their removal exceedingly difficult.

The sources of MPs in agricultural soils include various plastic products commonly used in conventional farming, such as greenhouse covers, mulch, seed packaging materials, underground plastic pipelines, and coated fertilizers (Akça and Ok, 2022). Additionally, MPs can also be introduced into soils through irrigation water. The accumulation of MPs in soils affects the physicochemical properties of the soil, the mobility of nutrients, and the diffusion of moisture within the soil. As a result, microbial activity, plant growth, and development are impacted. The germination of seeds and the development of roots during germination are slowed, thereby adversely affecting agricultural production (Ibarra-Jiménez et al., 2011; Gong et al., 2015).

When fragmented, MPs can form a wide variety of shapes, including fibers, spherical beads, thin films, and irregular fragments, ranging in size from nanometers to millimeters in diameter (Souza Machado et al., 2018). Microplastics exhibit structural differences depending on the type of polymer. Studies conducted in different soil types have shown that MPs of the types PE (polyethylene), PP (polypropylene), and PS (polystyrene) are commonly found, measured in mg/kg or items/kg (He et al., 2018). Ramos et al. (2015) reported that residual PE plastic film is present in approximately 10% of agricultural soils.

Soils are the primary reservoirs of waste plastics, possessing 4 to 23 times higher plastic concentrations compared to water systems. These waste plastics can be transferred from water ecosystems to soil ecosystems, for example, through flooding or irrigation (Scheurer and Bigalke, 2018; Blasing and Amelung, 2018). In soil, MPs can move both horizontally and vertically and disperse within the soil-water interface. This dispersion can be influenced by soil biota, soil macropores (pores> 75 μm), soil aggregation, soil cracking, irrigation, agronomic practices such as tillage, as well as by rainfall and erosion (Guo et al., 2020; Rillig et al., 2017). The aforementioned factors contribute to the transport of MPs into subsurface drainage systems and their direct entry into adjacent surface waters (Wanner, 2021). While water erosion may be more pronounced in regions with high topography, drainage water is more significant in flat areas and former wetlands (Schultz et al., 2005).

Information regarding MPs that leach into drainage water and the concentrations of MPs in drainage water remains limited. In early research on this topic, models of MP flow from soil to water considered only erosion and surface runoff, neglecting the contributions of drainage water (Tagg and Labrenz, 2018; Horton et al., 2017; Nizzetto et al., 2016;

Hurley and Nizzetto, 2018). Investigating the sources, transport, and destinations of MPs in different aquatic ecosystems is of great importance for understanding their presence, distribution, and variability, which is crucial for addressing environmental pollution and agricultural activities.

Zhou et al. (2023) highlights the insufficiency of research on the presence of MPs in drainage waters. Although there are some studies on MPs in water bodies in our country, information regarding soil, MPs that leach into drainage water, and MP concentrations in drainage water is almost nonexistent. The Mediterranean region is one of the most intensively irrigated agricultural areas in our country. The content of water removed through drainage after irrigation in soil-water systems is an important indicator for various pollutants, including salinity, pesticide residues, and MPs. This study aims to detect and classify the presence of MPs in drainage water samples collected from 10 different drainage points within the irrigation system of the intensively farmed Berdan Plain.

MATERIALS AND METHODS

Description of the Study Site

In the Kulak and Aynaz Marsh, located in Tarsus District of Mersin Province, an area of 50,000 decares lies between elevations of -1 and 3 meters. This area, which originally functioned as a swampy lake due to its high groundwater level, underwent significant changes when the Aynaz Drainage Pump was put into operation in 1968, lowering the groundwater level to allow for the cultivation of annual crops during the summer months. In 1992, the addition of the Kulak Drainage Pump further controlled the groundwater level. As the local population shifted from annual crop cultivation to year-round greenhouse vegetable production, the rapid discharge of water accumulated through rainfall in the Kulak and Aynaz Marsh became necessary. This drainage system was constructed to protect the 50,000 decares of land used for year-round greenhouse vegetable production from severe damage during heavy rainfall (DSI 6. Regional Directorate report, 2019).

Sampling Procedure

Drainage water samples were collected from 10 different drainage channels of the Berdan Plain in the Tarsus-Aynaz Marsh on 09.08.2022. Each water sample was collected in a 1-liter dark brown glass bottle after being rinsed out several times with the sampling water. The bottles' caps were tightly closed and placed in a cooler for immediate delivery to the laboratory and were kept at 4µ in a refrigerator. Each of the sampling points was coordinated and illustrated as shown in Table 1 and Figure 1.

Sorting and Identification of Microplastics

Microplastics on filter papers were examined under a binocular stereomicroscope (Leica S8AP0, simple light, 1.0-8.0X Zoom). Suspected MPs were preliminarily identified and recorded based on their abundance, shape, size, and color, according to Zhang et al. (2018). Their images were captured with a camera. The MPs extracted from water samples were expressed as pieces per liter. The photographed particles were also measured using the Feret's diameter as part of the ImageJ v1.50i software.

Table 1. Information of each sampling points of drainage water

Points	Place	Latitude Longitude
1	D-2 upstream	671983 4081795
2	D-2 medium dense greenhouse location	666949 4080309
3	Downstream	663528 4078346
4	D-1-6 upstream	672857 4077932
5	D-1-6 medium dense greenhouse location	671631 4074703
6	D1-6 downstream	669431 4073066
7	D1-b Kulak pomp station downstream	670747 4072243
8	Midway between D1-a and D1-b	667786 4073846
9	D1-a downstream Aynaz pomp station	662782 4075765
10	Karabucak main drainage channel upstream	669802 4082884

Figure 1. Sampling points of drainage water

RESULTS AND DISCUSSION

The MPs that have been isolated from 10 drainage water samples were examined under a binocular stereo microscope and classified according to their number, shapes and colors (Table 2 and 3).

Microplastic Abundance

A total of 97 MPs and 1 mesoplastic were identified in the drainage water samples (Table 2). The quantity of MPs in each sample ranged from 5 to 21 pieces per liter. The highest concentration of MPs was found at the D-1-6 medium dense greenhouse location (Sample 5), with 21 pieces per liter. Both the D-2 medium dense greenhouse location (Sample 2) and D1-a downstream Aynaz pump station (Sample 9) recorded 12 pieces per liter. In the upstream area of D-1-6 (Sample 4), 11 pieces per liter were detected, while 10 pieces per liter were found midway between D1-a and D1-b (Sample 8). The downstream area (Sample 3) and the D-2 upstream location (Sample 1) each contained 7 pieces per liter. The Karabucak main drainage channel upstream (Sample 10) and the D1-6 Kulak pump station downstream (Sample 7) as well as the D1-6 downstream (Sample 6) recorded 6, 5, and 5 pieces per liter, respectively. As the data indicate, MPs were more prevalent in areas where greenhouses were moderately dense. In Switzerland's intensively drained and agriculturally active Seeland region, drainage water samples from agricultural soils were analyzed for (MP) (>100 μm) concentration and composition. The samples contained an average of 10.5 ± 9.5 MPs per liter, with the highest value recorded at 34.6 MPs per liter. This high number is noted as significant (Bigalke et al., 2022). In a study conducted by McGinnis (2021) in Illinois, USA, the total MP concentration in samples collected from four different drainage points was found to range from an average of 8,630 to 10,130 MPs/m^3.

Microplastic Shape

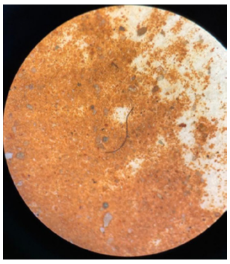
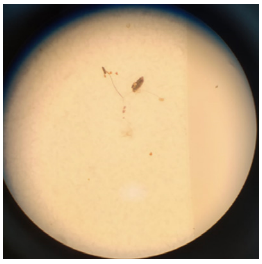
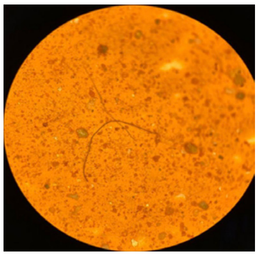
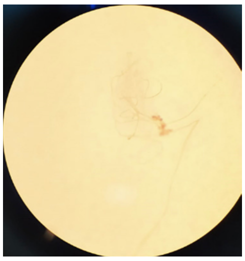
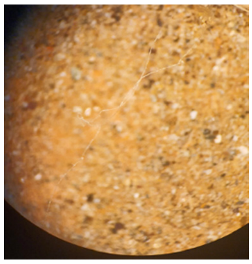
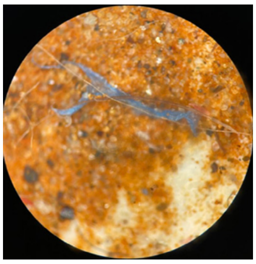
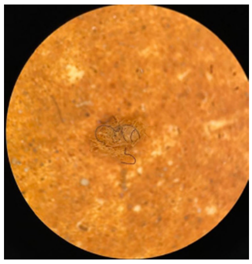
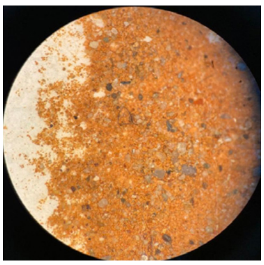
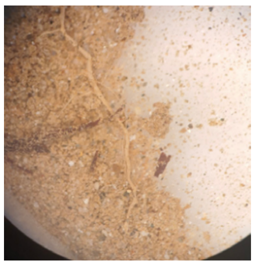
The types of MPs in the drainage water samples were identified as fibers and fragments, with fibers being the dominant type (Table 2, Figre 2). The fiber/threadlike shape was observed in 63.9% of the total pieces. The fragment shape appeared in 30.0% of the pieces. The fiber shape was observed in 5.2% of the pieces. A total of 34 black fibers were identified, with the highest number found in Sample 9 and the lowest in Sample 8. Additionally, in the moderately dense greenhouse areas, Samples 2 and 5 contained 17% and 12% fibers, respectively (Table 2). In a study conducted in Illinois, USA, it was found that in drainage waters, microfibers constituted 82% of the total MPs per cubic meter, fragments made up 17%, and pellets accounted for 1% (McGinnis, 2021).

Table 2. The basic properties of microplastics in drainage water samples

No	Shape	Color	Number (Pieces/lt)	Total
1	Fiber/threadlike	Black	5	10
	Fragment	White	3	
	Fragment	Blue	2	
2	Fiber/threadlike	Black	6	11
	Fiber/threadlike	Blue	1	
	Fiber/threadlike	Red	2	
	Fragment (long)	White	2	
3	Fiber/threadlike	Black	2	8
	Fiber/threadlike	White	1	
	Fiber/threadlike	Red	1	
	Fragment	White	4	
4	Fiber/threadlike	Black	3	10
	Fiber/threadlike	White	5	
	Fragment	White	2	

5	Fiber/threadlike	Black	3	21
	Fiber/threadlike	White	4	
	Fiber/threadlike (long)	Black	1	
	Fiber/threadlike	Blue	3	
	Fiber/threadlike	Red	2	
	Fragment	Blue	1	
	Fragment	Black	1	
	Fragment	White	6	
6	Fiber/threadlike	Black	2	5
	Fiber/threadlike	Blue	1	
	Fragment	White	1	
	Mezoplastic	Yellowish	1	
7	Fiber/threadlike	Black	3	5
	Fiber/threadlike	White	1	
	Fiber/threadlike (very long)	White	1	
8	Fiber/threadlike	White	1	10
	Fiber/threadlike	White	4	
	Fragment	White	5	
9	Fiber/threadlike	Black	7	12
	Fiber (long)	White	1	
	Fiber	Red	1	
	Fiber	Blue	1	
	Fragment	White	2	
10	Fiber	Black	2	6
	Fiber/threadlike	White	1	
	Fiber/threadlike	Red	1	
	Fiber/threadlike	Blue	1	
	Fragment	White	1	

Table 3. Microscope view of microplastic particles

Sampling Point	Microscope view	Sampling Point	Microscope view
1		6	
2		7	
3		8	
4		9	
5		10	

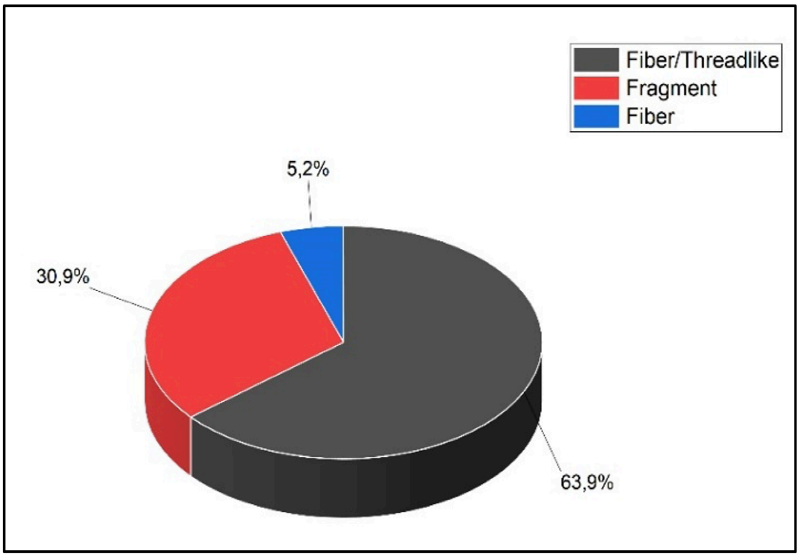


Figure 2. Shape of MPs

Microplastic Color

Black was observed in 35.7 % of the total pieces. White appeared in 45.9% of the pieces. Blue was identified in 10.2% of the pieces. Red was present in 7.1% of the pieces. Finally, the yellowish color associated with the mezoplastic material was observed in 1% of the pieces (Table 2, Figure 3).

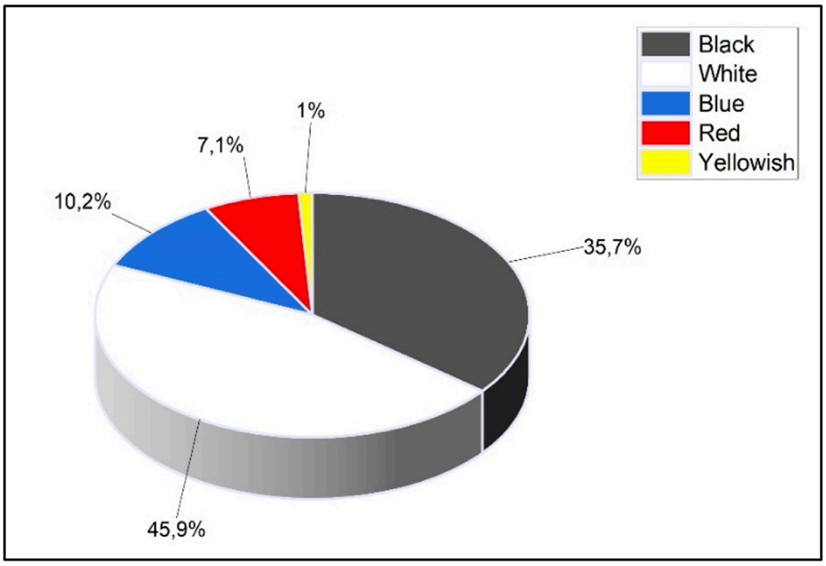


Figure 3. Color of MPs

Microplastic Size

The sizes of MPs detected in samples taken from certain points were measured. The sizes of MPs vary between 0.042 mm and 1.827 mm depending on the sampling points. This range indicates that the MPs found in the analyzed drainage water samples exhibit a variety of sizes, from very small to larger dimensions (Table 4). The smallest MP in terms of size was detected in sample number 5, measuring 0.042 mm. When considering the data, it can be said that the MP sizes found in sample number 5 are smaller compared to the others. This area is where the medium dense greenhouse is located. In samples numbered 7, 8, and 9, the sizes of MPs exceed 1 mm. These areas are where the pump stations are located. Of course, it is not possible to generalize with such a small number of samples. However, it can provide insights into the movement or transportability of MPs. Zang et al. (2022) determined that small-sized microplastics (< 1 mm) exhibit high mobility in horizontal or vertical directions in soil.

Table 4. Size distributions of microplastic particles

Sampling point	Dimension (mm)	Pieces
10	0.298	1
8	1.437	1
7	1.827	1
6	1.761	1
5	0.086	1
5	0.042	1
5	0.088	1
4	0.179	1
4	0.326	1
1	0.078	1
1	0.178	1

CONCLUSION

The presence of MPs in drainage waters has demonstrated that these particles can percolate through the soil surface, moving through soil pores, and ultimately reaching the drainage system. Fibers were found to be the predominant type of MPs. A higher concentration of MPs was observed in areas where greenhouses are located. The findings suggest that drainage outlets may serve as significant sources of MPs to the water bodies they eventually reach, potentially leading to substantial MP inputs into downstream systems such as drinking water reservoirs. This highlights the necessity of considering such contributions when addressing the MP cycle on both local and global scales.

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Optimizing Spatial Statistical Sampling for Profile Observations: Insights from Conditioned Latin Hypercube Design

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ABSTRACT

Extrapolating soil observations based on non-statistical sampling a machine learning-based (ML) spatial modeling framework can lead to biased and highly uncertain predictions. Accordingly, we emphasize that it is necessary to prepare a spatial sampling plan before the implementation of the ML-based soil mapping technique to avoid potential biases. In this study, we conducted a soil survey in a target area with profile observations at high-density observation per square km. We utilized high-resolution Planet Scope satellite imagery, specifically the R, G, B, and NIR bands, alongside variables representing vegetation, such as NDVI, and topography, such as elevation data derived from open-access EU-DEM. The statistical sampling procedure incorporated variables including slope, aspect, Topographic Wetness Index (TWI), Topographic Position Index (TPI), Multi-resolution Ridge Top Flatness Index (MRRTF), and Multi-resolution Valley Floor Flatness Index (MRVBF). As a method, the widely accepted Conditioned Latin Hypercube Sampling (CLHS) was employed, resulting in the selection of 30 profile points based on reported auxiliary environmental variables. The Bhattacharyya distance was used to analyze the relationship between the distribution of the original population (well, all study area pixel data) and the selected 30 samples covariate values. Bhattacharyya distance value of 0.54 indicates a medium difference overall. However, to better understand what this distance means necessary to explore the distribution and relationship of variables between data sets. We emphasize the importance of using algorithms such as CLHS to prepare sampling locations when the aim is to produce soil maps based on regression and/or classification models using ML algorithms.

Keywords: Spatial sampling, environmental covariates, digital soil mapping, soil survey

INTRODUCTION

Soil surveys are the primary way to collect soil data for effective management and sustainable use of soils (Moharana et al., 2024). At the scale of the study area, the traditional process begins with the identification of profile points for the lowest categorical level of Soil Taxonomy, "Series", using cartographic materials representing soil-forming factors. Thus, well known that the sampling process is of great importance for reducing fieldwork costs and for economic soil survey studies.

In soil survey literature, scientific knowledge is available in the selection of appropriate soil sampling techniques, and statistical sampling designs in which cartographic and digital data that can be used in the selection of soil profile points are integrated (Soil Science Division Staff, 2017). Recently studies have highlighted the effectiveness of the Conditioned Latin Hypercube Sampling (cLHS) schema (Minasny and McBratney, 2006) in different fields of study. However, in the selection of selected target profile points, statistical metrics that can represent the overall study area are integrated into metrics (Khan et al., 2023). This study aims to integrate cLHS for profile point selection specific to the number of target profiles in the study area and to quantify the similarity between the selected points and the study area by using high spatial resolution satellite images and topographic derivatives obtained from the digital elevation model.

MATERIALS AND METHODS

The study area is located between Isparta and Burdur, cities typically Mediterranean region. Western of Türkiye We used high-resolution PlanetScope satellite imagery (Planet Team, 2024), specifically the R, G, B, and NIR bands as well as Normalised Difference Vegetation Index (NDVI), alongside variables representing vegetation, and topography, such as elevation data derived from open-access EU-DEM (European Environment Agency, 2016). Slope (%), Aspect (°), Topographic Wetness Index (TWI), Topographic Position Index (TPI), Multi-Resolution Ridge Flatness Index (MRRTF), and Multi-Resolution Valley Floor Flatness Index (MRVBF) variables were calculated in the relevant DEM data via SAGA GIS software (Conrad et al., 2015). All covariates were presented in Figure 1.

The Conditioned Latin hypercube sampling (cLHS) method is a stratified random procedure that selects samples based on the distributions of the covariates. The cLHS strategy can be considered an optimization solution. Given data X, which is composed of n pixels with k environmental variables in a study area, the objective is to select m sample points so that the sampled points x (size m*k) form a Latin hypercube. The cLHS method was proposed by Minasny and McBratney (2006).

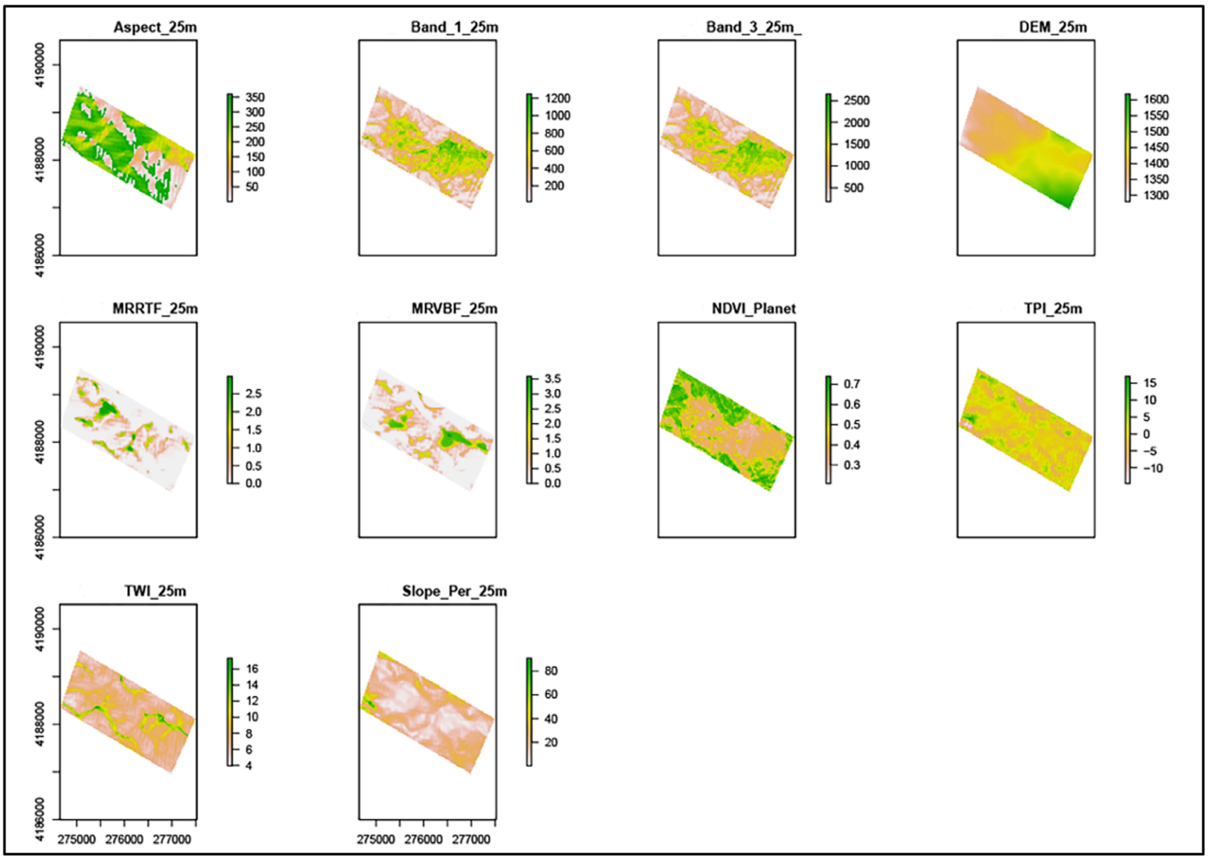

Figure 1. Raster environmental covariates are used as input to select sample points

clhs () function was used in the "clhs" package (Roudier, 2011) for CLHS procedure and bhattacharyya.dist () function in the "fpc" package (Hennig, 2024) for calculating the Bhattacharyya distance in the R Core Environment (R Core Team, 2022).

RESULTS

Based on a completely statistical procedure, this approach, in which each pixel is considered as an observation in terms of the resolution of environmental variables, resulted in the identification of 30 profile points. The CLHS procedure operates an iterative process and the evolution of the objective function for 1000 iterations is presented in Figure 2.

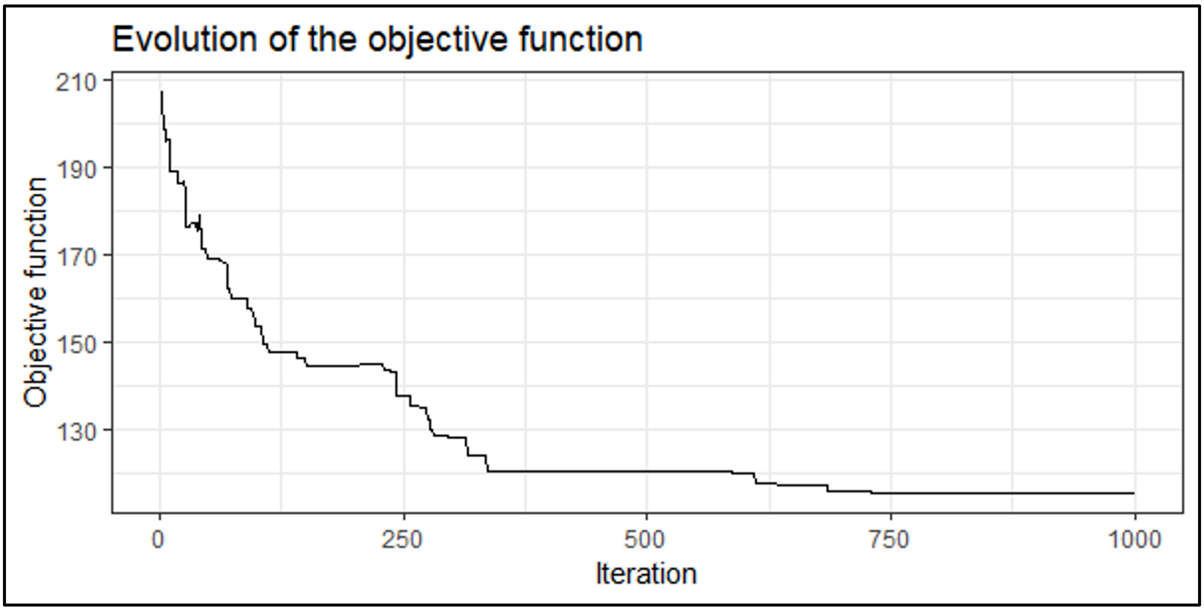

Figure 2. CLHS iteration result

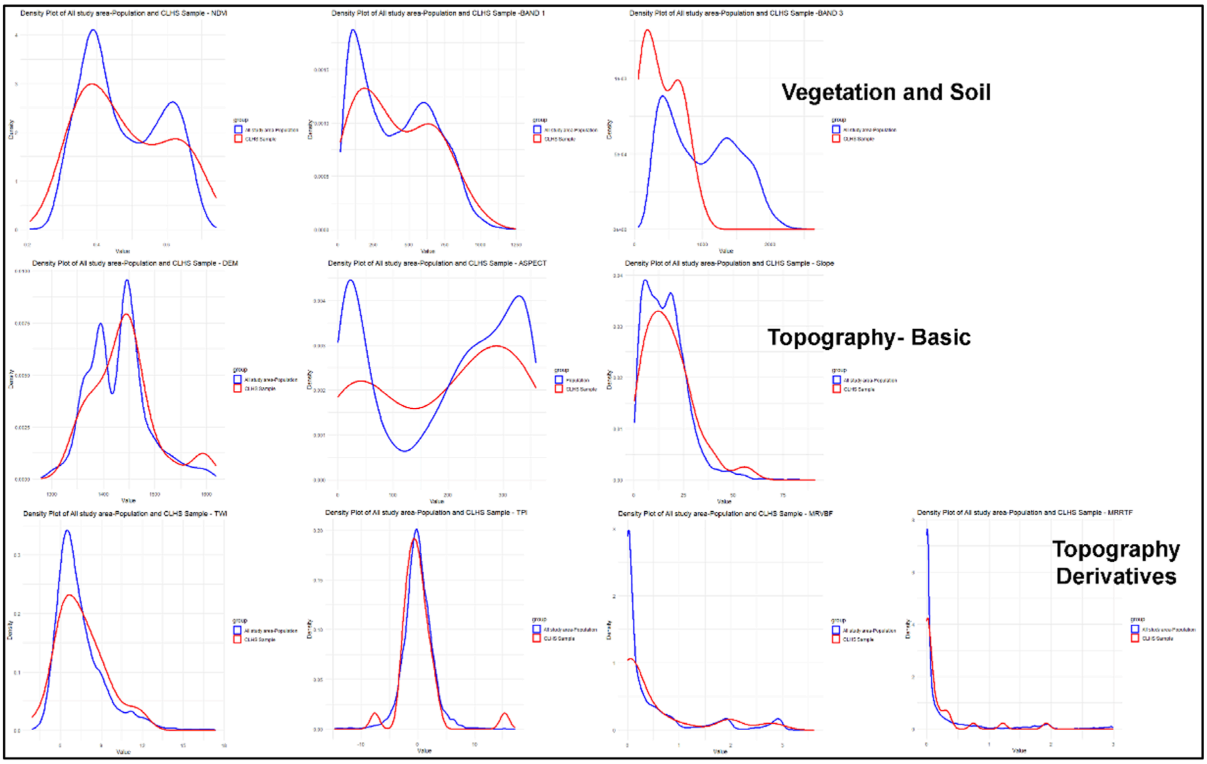

Figure 3. Density plots of both the entire area and selected points for each environmental covariate

Bhattacharyya distance was calculated at 0.54 and its value indicates a medium difference overall. However, to better understand what this distance means necessary to explore the distribution and relationship of variables between data sets. For this purpose, for each covariate, density graphs of both the entire area and selected points were drawn (Figure 3). Some covariates may be well represented at the selected points, while others may not be, depending on the study area.

In particular, when considering the density plot between the points selected for MRRTF and PlanetScope Band 3 and the entire area, the differences are remarkable (Figure 3).

DISCUSSION

Random sampling procedures may miss important parts of the geographic feature space. Therefore, this study emphasizes the importance of using algorithms such as CLHS to prepare sampling locations when the aim is to produce soil maps based on regression and/or classification models using ML algorithms (Moharana et al., 2024). The main limitation of our study is that we remain committed to our goal of a single sample size. Integration of different observation numbers and different statistical similarity measurement tools, considering sampling costs, is necessary. It should be emphasized that for some auxiliary variables, the MRRTF graphs may not appear to converge due to the narrow range of values for the auxiliary variable, and this situation may differ for sample size.

CONCLUSION

This study presents a methodology for selecting sample points in the created feature space using environmental variables for the target soil study area through conditioned Latin hypercube sampling (cLHS). In terms of auxiliary variables, differences between the selected points and the target study area were determined interpreted, and quantified using a statistical similarity measurement metric. Focusing on cost-benefit analysis-based sampling designs in determining the most effective sampling approach for soil surveys will increase the benefit.

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Assessment of Soil Erosion Risk in the Andırın River Catchment, Mediterranean Region, Türkiye

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ABSTRACT

The Andırın River catchment, located in the Mediterranean region, is characterized by a rich biodiversity, encompassing diverse soil types, hydrology, and vegetation. This study aimed to assess the effects of land use and cover changes on soil erosion risk within the catchment. For this purpose, land use patterns were mapped using remote sensing techniques, while topographic features were identified using geographic information systems (GIS) techniques. Additionally, a CORINE erosion risk map was created for the entire catchment to estimate both potential and actual soil erosion risks. The results indicate that the potential soil erosion risk in the Andırın River catchment is significantly high, with 79.5% of the area at risk. However, the actual risk of soil erosion is considerably lower, , at 26.8%, due to the mitigating effects of dense vegetation cover. This vegetation plays a crucial role in reducing soil erosion, even in areas characterized by steep slopes, which are typically more vulnerable to erosion process. In conclusion, while the Andırın River catchment benefits from natural vegetation cover that helps curb soil erosion, continued monitoring and effective land use policies are crucial for sustaining the soil and ecological health of the region. The integration of GIS and remote sensing in the assessment of erosion risk proved to be an effective approach in identifying vulnerable areas, allowing for more informed decision-making regarding land management and conservation efforts.

Keywords: CORINE erosion risk map, geographic information systems, land use, Mediterranean region, remote sensing, river catchment

INTRODUCTION

Soil erosion is considered a global problem with serious impacts on the environment, agricultural productivity, and sustainability (Specht, 2009). Erosion is usually influenced by natural factors such as vegetation density, topographical features, climate variables, and soil structure. However, human activities also accelerate this process, leading to reduced vegetation cover and increased rates of soil erosion (Alexakis et al., 2013). Deforestation, improper land use, and intensive agricultural activities are among the primary human-induced factors of erosion.

Therefore, studies aimed at understanding the causes and dynamics of soil erosion are crucial for predicting future soil losses and developing strategies to mitigate these losses. These studies also play a critical role in balancing the sustainable use of natural resources with ecosystem conservation. Particularly for watershed management and riparian (coastal) areas, such studies are important both regionally and nationally (Bayramin et al., 2006).

In the Mediterranean region, the conversion of local vegetation to agricultural activities over many years has triggered soil erosion and land degradation (Evrendilek et al., 2004). This transformation has led to the deterioration of natural ecosystems and the decline of fertile agricultural lands. About 25% of agricultural lands in Europe (72 million ha) consist of pastures, and 35% (54 million ha) are forest areas, with serious land degradation detected in 92% (26 million ha) of these areas (Van Lynden, 1995). In Turkey, 59% of agricultural lands and between 54% and 64% of pastures are subject to moderate levels of erosion (Doğan, 2002). These figures indicate that land degradation is a widespread issue for both Turkey and Europe.

Changes in land cover within a catchment not only create additional challenges for agricultural and urban water supply but also lead to significant changes in ecosystems. The expansion of agricultural lands and urbanization activities cause ecological changes similar to deforestation, disrupting the natural balance (Makino et al., 1997). Land degradation in mountainous areas is triggered by natural factors such as soil loss and mass movements, and when combined with improper land uses, these processes accelerate (Shrestha et al., 2001). Soil losses occurring on steep slopes, in particular, seriously threaten the ecosystem balance in the region.

Soil organic matter is critical for soil quality and health, and it is strongly influenced by agricultural management practices. Organic matter directly and indirectly affects soil erosion by improving soil porosity and water retention capacity, as well as by reducing surface runoff (Boyle et al., 1989).

The European Commission launched the CORINE (Coordination of Information on the Environment) program in 1985 to collect environmental data and assess the impacts of community environmental policies. This program is important for understanding various environmental components, the status of natural regions, and their geographical distribution (Heymann, 1994). The CORINE methodology is a standard technique used by European Union countries to determine erosion risks and regional characteristics. The CORINE (Coordination of Information on the Environment) methodology is based on the Universal Soil Loss Equation (USLE) model of the United States (Wischmeier, 1976) and was developed by the European Union. The main advantage of the CORINE model is that it addresses erosion concepts in a comprehensive approach that covers the entire study area. With this methodology, EU countries in the Mediterranean region have developed erosion risk maps and land cover distributions.

Initially, the CORINE Land Cover (CLC) Program developed a method to collect land cover data from satellite images. This method used limited image processing and geographic information systems (GIS) software. The advantages of the method have been proven and remain valid (Berney et al., 1997; Kim, 2006). The CORINE methodology and soil erosion risk maps hold great importance for future scientific studies between the European Union and Turkey (Bayramin et al., 2006).

MATERIAL AND METHODS

Characteristics of the Study Area

This study was carried out in the Andırın River basin, located in the Kahramanmaraş province of Turkiye. The study area is situated to the west of Kahramanmaraş, between 37°35’ - 37°22’4’’ North latitude and 26°28’16’’ - 36°16’06’’ East longitude (Figure 1). The area covers approximately 21,280 hectares.

The study area has a typical Mediterranean climate, characterized by cold, rainy winters and hot, dry summers. The average annual temperature is 16.7°C, and the total annual precipitation is 721.6 mm, with the majority of the precipitation (366.8 mm) occurring in the winter months. The region typically receives high amounts of rainfall, with daily maximum rainfall levels reaching up to 100 mm (Anonymous, 2024). According to Soil Taxonomy, the area is classified under xeric (dry) moisture regime and a thermal temperature regime, reflecting the characteristic climatic and soil conditions (Soil Survey Staff, 2000).

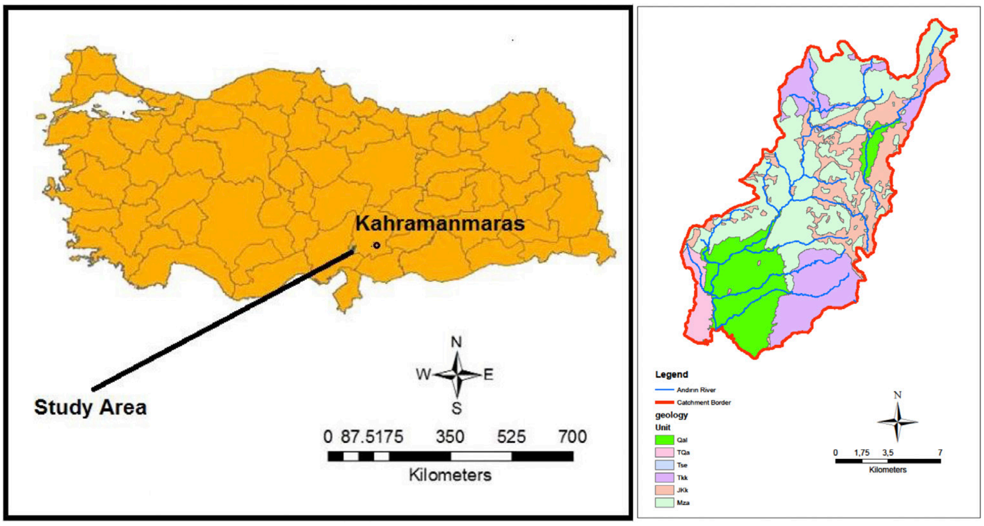

Figure 1. Study area

CORINE Erosion Risk Mapping Method

The CORINE model was utilized to assess erosion risk by incorporating several key parameters such as soil erodibility, erosion effectiveness, slope, and vegetation cover (Van der et al., 2000). These factors are classified into four groups, forming the basis for evaluating the erosion hazard in a given area. The model assesses erosion risk through two concepts: potential erosion risk and actual erosion risk (Giordano, 2009). Potential erosion risk refers to the theoretical risk based on topographic and soil conditions, without considering vegetation cover, while actual erosion risk accounts for the mitigating effects of vegetation. Figure 2 presents the logic and strategy underlying the CORINE model's approach.

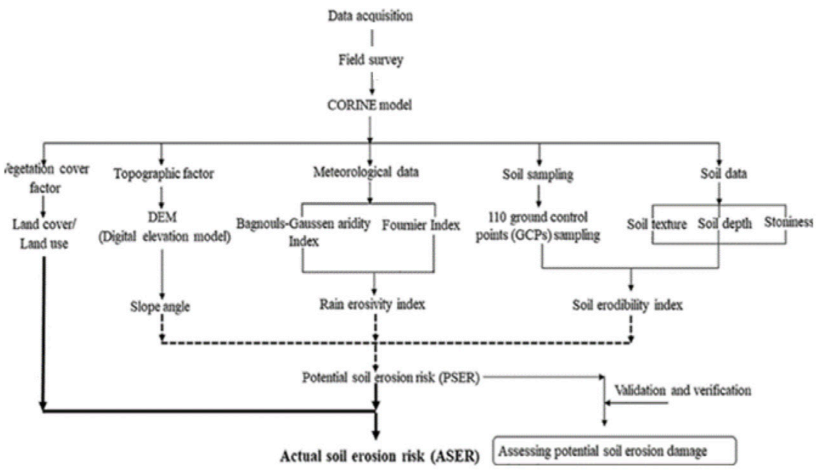

Figure 2. CORINE erosion risk assessment (Adapted from EEA, 2000)

Soil Erodibility

Soil erodibility is an important parameter that indicates the natural risk of soil erosion in an area, regardless of current land use or vegetation cover. It reflects a worst-case scenario, allowing us to understand how vulnerable the soil is to erosion. Soil erodibility is based on the physical characteristics of the soil structure and reveals the potential for soil loss, which directly impacts erosion risk. Erodibility represents a value derived from factors like soil texture, soil depth, and stoniness, which determine how easily the soil can be dispersed and transported by the impact of raindrops. Finer soils (e.g., clay and silt) are more erodible, while coarser soils (e.g., sandy soils) tend to be less prone to erosion. Stoniness also plays a role in reducing erosion by slowing down surface runoff. To determine potential erosion risk, the soil erodibility layer, erosion effectiveness layer, and slope layer are first produced. In the CORINE method, soil erodibility is calculated using the formula below, considering soil texture, depth, and stoniness (Heymann 1994):

$$\textit{Soil Erodibility} = \textit{Soil Texture} * \textit{Soil Depth} * \textit{Soil Stoniness} \qquad [1]$$

In this study, Geographic Information Systems (GIS) data layers were created for each erodibility parameter (soil texture, depth, and stoniness). These layers were produced using a 1:25,000 scale soil map (KHGM, 1997) (Akay et al., 2008). The soil erodibility map was created using the “Raster Calculator” tool in the “Spatial Analyst” extension of ArcGIS v10.2 software (Ormsby, 2004). Based on the obtained soil erodibility index, the study area was divided into three main categories: (1) low erosion risk, (2) medium erosion risk, and (3) high erosion risk (Akay et al., 2008). Additionally, in areas without natural vegetation or soil cover (e.g., bare rock, urban areas, and water bodies), the index value is considered 0, indicating no erosion risk in these regions (Briggs et al., 1992).

Erosion Effectiveness (Erosivity)

In the CORINE model, erosion effectiveness (erosivity) is calculated by combining two climate indices: the Fournier Index (FI) and the Bagnouls-Gaussen Aridity Index (BGI). Erosion effectiveness describes the process of soil separation and transportation caused by the impact of raindrops and surface runoff. The impact of raindrops disperses the top layer of the soil, initiating erosion. This process varies depending on the amount and intensity of rainfall, making the accurate evaluation of climate data critical in erosion risk analyses (Lal, 1994).

The erosion effectiveness index is calculated by combining the Fournier and Bagnouls-Gaussen indices as follows:

Erosion Effectiveness Index = FI Index * BGI Index ***[2]***

The Fournier Index (FI) was developed to assess erosion effectiveness on a regional scale (Fournier, 1960). FI measures the variability of precipitation in a region, determining its sensitivity to erosion. However, ignoring the contribution of short-term intense storms may lead to underestimation in some cases. Therefore, the Modified Fournier Index (MFI) is used for more accurate assessments, calculated using monthly total precipitation (Pi) and annual average precipitation (Pa) (Arnoldus, 1980).

The Modified Fournier Index, by accounting for the impact of extreme weather events, provides more reliable results. For example, precipitation intensity in the Mediterranean climate can vary depending on the topographic structure, accelerating the erosion process (Dengiz and Akgül, 2005). Although the Fournier Index is an acceptable measure of rainfall variability, soil erosion may increase if soil moisture stress caused by vegetation loss is not considered (Zhu, 2012).

The Bagnouls-Gaussen Index (BGI) evaluates the aridity and moisture conditions of a region and provides additional climate information alongside the Fournier Index.

$$FI = \sum_{i=1}^{12} \frac{P_i^2}{P} \quad [3]$$

$$MFI = Pi / Pa \quad [4]$$

$$BGI = \sum_{i=1}^{12} (2t_i - P_i)k_i \quad [5]$$

Slope

Slope angle is one of the most important factors determining the susceptibility of soil to erosion, as surface runoff increases with steeper slopes, raising the risk of soil loss. The slope data used in the study were derived from digital topographic maps produced at 10-meter contour intervals and were used as the primary data source for creating digital elevation models (DEM). DEM data represent the topography of the region with high accuracy, and slope percentages were calculated and classified. In accordance with the CORINE methodology, slope percentages were divided into four main classes: 1 (0-5%), 2 (5-15%), 3 (15-30%), and 4 (greater than 30%) (Parlak et al., 2007). This classification allows for analyzing the slope distribution in the study area and evaluating the erosion risk in different slope categories. Slopes greater than 30% are particularly highlighted as high erosion risk areas.

Vegetation Index

Vegetation plays a crucial role in preventing soil erosion by reducing surface runoff and protecting the soil from the impact of rainfall (Trimble and Crosson, 2000). Vegetation softens the impact of raindrops on the soil and facilitates slower water infiltration, reducing erosion risk. However, inappropriate land use and continuous agricultural activities, especially on sloped lands, lead to vegetation degradation and increased erosion risk (Millward and Mersey, 1989). Proper vegetation management can significantly reduce erosion, and reliable land use and vegetation data are essential for accurate erosion risk modeling (Yüksel et al., 2008).

The vegetation and land use status of the study area were identified using forest stand maps (OGM, 2010), digitized in the GIS environment. These data were reclassified according to the CORINE Land Cover Classification System for inclusion in the study's analyses. The classification includes different land use types such as agricultural lands, forests, meadows, and urban areas. Finally, vegetation is classified into two main categories in the CORINE model: fully protected and not fully protected areas. Forest units, which provide the best soil protection, are classified as "fully protected," while agricultural lands and natural meadows are included in the "not fully protected" category.

Potential Soil Erosion Risk

Potential soil erosion risk is a risk calculated independently of land cover to reveal the natural erosion potential in an area. This calculation is based on the soil erodibility index, erosion effectiveness (erosivity) index, and slope class parameters. Potential erosion risk does not consider current land use and vegetation, thus reflecting the worst-case scenario. This risk is calculated using the formula:

Potential Soil Erosion Risk = Erodibility Index * Erosivity Index Class * Slope Class [6]

This formula combines natural factors such as soil structure, climate conditions, and slope to evaluate the erosion potential of the region. As slope increases, so does erosion risk, making accurate determination of slope classes and erosivity parameters critical for accurately calculating erosion risk.

Actual Erosion Risk

The actual erosion risk index is based on estimating the erosion risk depending on the current land use and vegetation conditions (Giordano, 2009).

RESULTS AND DISCUSSIONS

CORINE Erosion Risk Map

The soil erosion risk in the study area was estimated using the CORINE method, incorporating various parameters such as soil erodibility, slope, erosivity, and land use intensity (Aydın and Tecimen, 2010). The assessment followed a two stages process. In the first stage, key factors influencing soil erosion including soil texture, soil depth, stone content, slope angle, soil erosivity factors (MFI and BGI), and vegetation cover, were considered. These parameters were obtained through field observations and data provided by relevant official institutions. The second stage involves reclassifying the collected data within a Geographic Information System (GIS) environment. This allowed creation of soil erodibility and erosivity layers, which were then integrated to determine the overall soil erosion risk following the CORINE methodology. By leveraging GIS, the study effectively visualized spatial variations in erosion risk, enabling a more nuanced understanding of how each factor contributes to overall soil vulnerability. The integration of both physical and land use factors into the model offers a comprehensive framework for evaluating erosion hazards, making it a critical tool for land management and conservation planning.

Potential Soil Erosion Risk

The potential soil erosion risk was estimated by combining key factors such as soil erodibility (determined by soil texture, soil depth, and stoniness), soil erosivity (measured by the Modified Fournier Index (MFI) and Bagnouls-Gaussen Index (BGI), and topographic conditions (Figure 3a). This combination enabled the division of the region into four main erosion risk categories: no risk, low, medium, and high. The analyses revealed that the dominant category is the high-risk zone, which comprises 79.5% of the study area. These high risk zones are predominantly found in karstic or ophiolitic mountainous regions with steep rainfall (79.5%) and high rainfall, making them particularly susceptible to erosion. In contrast, about 5.1% of the area falls under the “little or no risk” category, indicating relatively stable soil conditions. These lower-risk areas are typically found in flatter terrains or regions with dense vegetation cover, which act as protective barriers against erosion. The classification of the region into different risk categories provides valuable insights for targeted soil conservation measures and highlights the critical areas where erosion prevention efforts should be prioritized.

Areas with high and medium current erosion risk are generally concentrated in steep and vegetation-deficient regions. Flat or gently sloping areas, if completely unprotected, are also included in this risk category. In contrast, areas with high vegetation cover, particularly in the northwestern part of the study area, are assessed as having low or medium levels of current soil erosion risk. On the other hand, regions with slopes greater than 30% are mostly classified as high current erosion risk areas. These findings clearly demonstrate the protective effect of vegetation against soil erosion.

Vegetation, especially in sloped areas, increases soil stability by preventing surface erosion and mass movements. However, the removal of vegetation accelerates erosion and soil displacement on sloped terrain. In the potential erosion risk map of the study area, areas classified as high erosion risk dropped from 79.5% to 26.8% when considering the presence of vegetation. This result indicates that vegetation has a significant impact on reducing soil erosion. Similar findings have been reported in other studies investigating the relationship between soil erosion and vegetation (Lal, 1994; Yüksel et al., 2008; Aydın and Tecimen, 2010).

Actual Erosion Risk Map

Soil erosion indicators provide a snapshot of the degree and severity of potential and current soil erosion risks. Potential erosion risk estimates consider the region's climatic, topographic, and edaphic (soil-related) conditions to determine the likelihood of erosion. This approach helps us understand how naturally prone the soil is to erosion. On the other hand, current erosion risk provides a more realistic assessment by considering both vegetation cover and current land use (Figure 3b). Vegetation protects the soil from erosion effects, while land use determines whether the soil is being protected or whether its erosion risk is increasing.

Indicators not only provide information about current erosion risk but also offer insights into soil loss rates and soil loss tolerance under existing soil management and erosion control practices. This information plays a critical role in assessing the effectiveness of soil management strategies. Specifically, determining whether current soil loss rates exceed acceptable tolerance levels helps us predict the future success of sustainable land management practices.

Comparing potential and current soil erosion risks is essential for analyzing the impact of changes in land use on erosion risk. This comparison can reveal how activities such as agriculture, deforestation, or urban development alter the natural structure of the soil and increase risks (Düwel and Utermann, 1999). As a result, it may highlight the need to review current land use policies and implement more effective erosion control strategies.

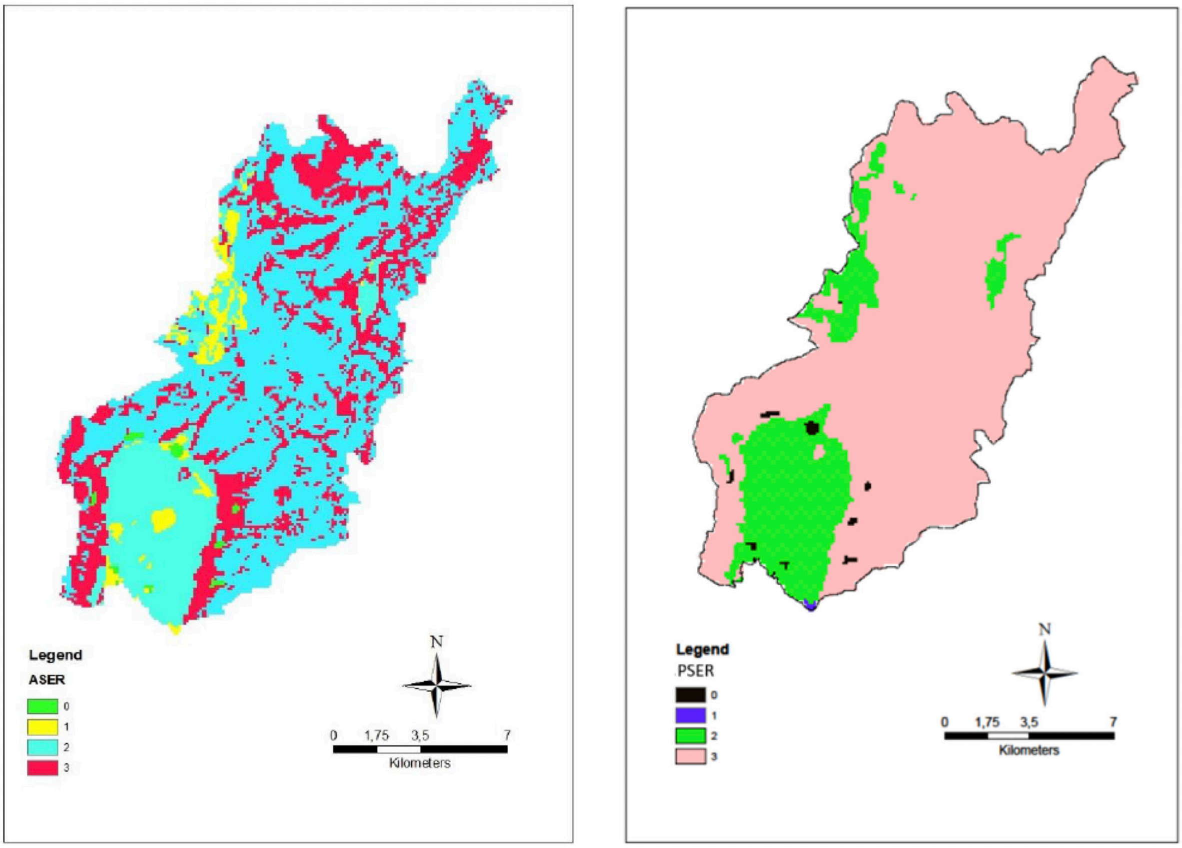

Figure 3. a) Actual and b) Potential and soil erosion risk map of the Andırın river catchment

Erosion Risk Assessment

Impact of Soil Erosivity

Rainfall erosivity is primarily associated with the amount and intensity of precipitation. In the context of USLE (Universal Soil Loss Equation), erosivity is calculated by multiplying the total dynamic energy of rainfall with the maximum 30-minute rainfall intensity. This value is obtained by summing these factors for all storms during a specific assessment period (Mondal et al., 2016). Measurements conducted in the Andırın Stream basin determined the "Fournier precipitation index" as 162, indicating a very high erosion risk relative to the amount of rainfall. Additionally, the "Bagnouls-Gaussen Drought Index" was calculated as 193, signifying considerable drought stress in the region (Doğan, 2000). According to this evaluation, the "Bagnouls-Gaussen Drought Index" was classified as 5, and the erosivity index as 3, revealing the significant direct impact of rainfall and drought on soil erosion in the basin.

Impact of Soil Erodibility

The soil erodibility map of the study area was created by combining factors such as soil texture, depth, and rock content in a GIS environment. Based on the data, 78.4% of the study area consists of highly erodible soils, 14.8% of moderately erodible soils, and 6.8% of low erodibility soils. Soil erodibility is heavily influenced by soil texture, organic matter, structure, stoniness, and depth. These properties directly determine the soil's water retention capacity, permeability, and resistance to sediment detachment (Aydın and Tecimen, 2010; Knapen et al., 2007). Soil permeability is a key component of erodibility, indicating how quickly soils can absorb rainfall and manage flood risk. Soil texture and land use (e.g., forests or urban areas) are also significant factors affecting soil erodibility (Qi et al., 2008).

The majority of the study area consists of coarse-textured, highly permeable soils, such as sandstone and mudstone. Clay soils, derived from limestone, are located in the western part of the basin. Soil texture influences detachment, transport, and deposition processes in water-induced soil erosion. Especially, silt particles are easily transported by water flow, compared to finer (clay) or coarser (sand) materials. Therefore, soils with high silt content are more prone to erosion (Briggs et al., 1992; Lal, 1994).

In much of the study area (60.7%), soil depth is less than 25 cm. This shallow depth leads to higher erosion rates due to reduced water retention capacity and increased surface runoff (EEA, 2000). As soil depth increases, more rainfall is absorbed and surface runoff decreases, acting as a significant factor in erosion prevention. However, eroded soil profiles allow less rainfall to infiltrate, logically resulting in more erosion (Trimble and Crosson, 2000). Surface rocks can slow the erosion process by reducing raindrop impact on soil aggregates, although once surface runoff begins, the presence of rocks may increase water turbulence and promote gully erosion.

Increasing soil depth contributes to reducing erosion risk by allowing soils to absorb more rainfall and decreasing surface runoff (Briggs et al., 1992). Despite the high erosion risk in most of the study area, management strategies can mitigate this risk.

Impact of Topographic Features on Erosion

Slope is one of the most important factors affecting surface runoff and soil erosion. As slope increases, significant effects are observed on net rainfall excess, surface runoff depth, flow velocity, and shear stress (Liu et al., 2001). On sloped lands, the higher water transport capacity increases sediment transport risk. However, in the context of USLE, the effect of slope is considered a measure of water's sediment transport capacity in the landscape. This approach is debated, as it doesn't fully account for all hydrological processes affecting slope-driven water flow and erosion (Moore and Burch, 1986).

The slope data layer in the study area was derived from the Digital Elevation Model (DEM) and classified according to the CORINE methodology. The results indicate that the average slope of the study area is 22%, with 66.2% of the area consisting of steep and very steep slopes above 15%. These steep terrains, primarily located in the northern part of the study area, experience accelerated surface runoff due to the high slope, significantly increasing soil erosion. In contrast, the southern part of the area has slopes below 15%, characterized by gentle to moderate slopes. On these lower slopes, surface runoff is slower, resulting in a lower erosion risk. Slope affects not only the direction and speed of water flow but also the likelihood of soil particle displacement. Increased net rainfall excess, surface runoff depth, and shear stress in sloped areas raise the sediment transport by water, accelerating the erosion process (Aydın and Tecimen, 2010).

Effects of Land Use

In the study area, forest units are classified as “fully protected,” while cultivated lands and natural pastures are categorized as “not fully protected.” In this context, 45.1% of the study areas are classified as fully protected (e.g., forests, dense shrubs) and 54.9% as not fully protected (e.g., agricultural lands and open areas). Vegetation plays a critical role in preventing erosion by reducing surface runoff and protecting the soil from rainfall impact (Trimble and Crasson, 2000). Therefore, land use and land cover (LULC) data are essential in soil erosion studies.

Changes in land use can significantly impact the distribution of organic carbon content in the soil profile (SOC). In this study, it was observed that the concentration of organic matter in surface soils was significantly higher in shrub/oak and natural pasture areas compared to deep soils. However, in agricultural areas, the difference in SOC concentration between surface and deep soils was smaller, with a moderate difference observed in forest areas. This high organic matter content in surface soils is mainly due to the high proportion of plant residues (Li et al., 1992).

Research on the rehabilitation of degraded soils in southern Brazil has shown that management systems’ effects on soil organic matter accumulation rates are closely related to soil components and climate conditions, with temperature and rainfall amount being important factors (Alvarez and Lavado, 1998). The combination of farming and processing systems with these soil and climate variables can result in a wide range of soil organic matter accumulation rates. In tropical and subtropical regions, no-tillage (NT) methods have been adopted as a primary management strategy, helping increase soil organic matter. The highest increase is observed in the surface layers of soil, with a net increase in total organic matter storage in soils at a depth of 0-30 cm. Such management systems contribute to the soil acting as a carbon sink and reducing atmospheric CO2 emissions (Bayer et al., 2000).

Agricultural lands may be prone to either carbon loss or gain, depending on the management practices employed. For instance, converting forest land into agriculture can result in up to a 50% reduction in SOC levels (Lal, 2005).

The restoration of vegetation typically helps maintain the balance of soil organic carbon, reaching a new equilibrium over time. Zak et al. (1990) reported that cultivating shrubs and trees over 25 years contributed to higher SOC levels. High SOC levels in shrub/oak areas suggest that converting agricultural lands to such vegetation types could increase organic matter.

CONCLUSION

First, the land use extent in the Andırın River basin was mapped using Geographic Information Systems (GIS) according to the CORINE Land Cover Classification. The study area includes various land use types, such as continuous urban areas, intermittent urban areas, non-irrigated agricultural lands, permanently irrigated agricultural lands, fruit tree orchards, broad-leaved forests, coniferous forests, mixed forests (shrubs), and natural pastures. These land uses were divided into two main classes by the CORINE Erosion Risk Model: fully protected areas and non-fully protected areas.

To simplify the structure and parameterization of the model, potential soil erosion risk (PSER) and actual soil erosion risk (ASER) were evaluated using the CORINE model in a GIS environment. The main parameters used to assess soil erosion risk were soil erodibility, erosion potential, slope, and vegetation cover. The criteria determined for each parameter were integrated to produce potential and actual soil erosion risk maps using raster-based analysis.

The results show that 79.5% of the study area is at high potential soil erosion risk. However, the actual soil erosion risk is lower, with 26.8% of the basin evaluated as having high actual soil erosion risk. Areas with high actual soil erosion risk are concentrated mainly on the steep slopes on both sides of the Yeşilyurt Plain and the northern slopes where forests have been converted to agriculture.

Vegetation cover plays a significant role in reducing erosion risk. Adding the vegetation layer to the model reduced the proportion of areas classified as high erosion risk from 79.5% to 26.8%. This clearly demonstrates the critical role of vegetation in soil protection. Despite the steep slopes in the southern part of the study area, these regions were classified as having low to moderate actual soil erosion risk due to the density of the vegetation cover.

Changes in land use can directly affect soil properties or accelerate the erosion process. Converting forested areas to agriculture, in particular, can make soil protection more challenging and increase erosion risk. Therefore, proper land use management and the protection of vegetation are essential for preventing soil erosion.

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Effects of Vegetation and Land Use on Soil Properties in the Riparian Zones of the Andırın River, Mediterranean Türkiye

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ABSTRACT

The riparian zone of the Andırın River, a characteristic Mediterranean ecosystem, is shaped by its distinct combination of soil, hydrology, vegetation, and anthropogenic influences. This study aims to assess the impact of different land uses on the physical and chemical properties of soil in the riparian zone of the Andırın River, located in Kahramanmaraş, Turkey. Soil samples were collected at distances of 2, 10, and 25 meters from both sides of the river, across four land use types: irrigated agriculture, rainfed agriculture, oak forest, and pine forest. The physical and chemical properties analyzed included soil texture (sand, silt, and clay), aggregate stability, hydraulic conductivity, pH, electrical conductivity, organic matter, carbonate content, and available potassium and phosphorus. The results showed that soils from irrigated agricultural areas, especially those within 2 meters of the river, had the highest sand content. In contrast, clay content increased as the distance from the river widened. Pine forest soils exhibited significantly higher aggregate stability compared to those under other land uses, indicating better soil structure. Furthermore, soils from oak and pine forested areas demonstrated higher hydraulic conductivity than those in agricultural areas, regardless of the distance from the river. The chemical properties of the soils in the riparian zone did not exhibit significant variation with distance from the river. However, organic matter content in soils from irrigated agricultural areas was noticeably lower than in soils under other land uses. This reduction in organic matter is likely due to hydrological irregularities of the river and the negative impact of human activities on vegetation. These findings highlight the sensitivity of riparian soils to land use changes and underscore the importance of sustainable land management practices in maintaining soil health in these fragile ecosystems.

Keywords: Land use, physical and chemical soil properties, riparian zone

INTRODUCTION

Coastal zones are typically areas adjacent to freshwater surfaces such as rivers, streams, creeks, lagoons, ponds, and lakes (Fischer et al., 2001; Gregory et al., 1991). These zones exhibit complex and dynamic interactions between biological, chemical, and physical processes, making them vital for numerous ecosystem functions. Among these functions are the regulation of water flow, protection of water bodies from excessive sediment load, reduction of shoreline erosion, and the creation of habitats for a wide variety of aquatic organisms. Additionally, coastal zones provide essential shade, which regulates water temperature and supports aquatic biodiversity. Given their crucial role, coastal zones act as natural buffers that protect both groundwater and surface water quality from the adverse effects of various land use activities. Moreover, they serve as unique areas that help in controlling and mitigating non-point source pollution, playing a vital role in water purification. These zones also provide food and habitat for many plant and animal species, making them indispensable for biodiversity conservation. Because of these significant ecological and hydrological benefits, preserving the functions of coastal zones through conservation measures is of utmost importance (Hawes and Smith, 2005; Whitman, 2009; Zaimes et al., 2007).

Water flow is perhaps the most critical and visible phenomenon within terrestrial processes, as it directly influences a region's ecological balance. The hydrological structure of stream networks in a given area serves as a comprehensive indicator of water movement and the overall characteristics of the natural environment. Changes in environmental conditions, particularly those related to vegetation cover and land use patterns, can have profound effects on the dynamics of water flow and the efficiency of regional water systems. Alterations in vegetation or land use disrupt the delicate balance between precipitation, evaporation, infiltration, and surface flow, further complicating water management in the affected areas (Ghafari et al., 2009). This is particularly important in regions like the Mediterranean, where water resources are often scarce and irregularly distributed throughout the year.

Furthermore, coastal zones function as crucial interfaces between terrestrial and aquatic ecosystems, facilitating the exchange of nutrients and carbon between these environments (Wang et al., 2005; Gong et al., 2015). A substantial portion of physical and chemical substrates, including essential elements such as nitrogen (N), is discharged from water bodies and streams into the surrounding terrestrial areas (Vought et al., 1994; Groffman and Crawford, 2003; Liu et al., 2016). This nutrient exchange is essential for maintaining the health of both wetland and upland ecosystems, as it supports plant growth and enhances soil fertility. However, imbalances in this nutrient flow, often caused by human activities, can lead to issues such as eutrophication in nearby water bodies.

Soil properties within coastal zones are particularly sensitive to various environmental processes, including soil erosion, sediment transport, periodic flooding, oxidation-reduction reactions, and salinization or alkalinization (Graf-Rosenfellner et al., 2016). In addition to natural processes, soil is often negatively impacted by agricultural practices, particularly the use of pesticides and chemical fertilizers. These practices can degrade soil quality over time, affecting its physical structure and chemical composition. Therefore, understanding and characterizing soil properties along coastal zones is critical for implementing effective conservation practices at appropriate scales. Effective management of these areas can help mitigate the detrimental effects of improper land use and maintain the ecological balance needed for sustainable water and soil resources (Whitman, 2009).

The hydrological characteristics of rivers in the Mediterranean region are heavily influenced by the region's distinct climate and geographical features. These rivers typically display an irregular flow regime, with their water levels fluctuating in response to the Mediterranean climate. During the winter months, when rainfall is abundant, water levels rise, resulting in higher river flows. Conversely, during the dry summer months, water levels decrease dramatically, and many small rivers may even dry up entirely (Atalay and Mortan, 2003). These seasonal variations in water availability have significant implications for the ecosystems dependent on river flow, as well as for agricultural and urban areas that rely on consistent water supplies.

In addition to natural environmental factors, human activities exert considerable pressure on coastal zones, often exacerbating the negative impacts on these fragile ecosystems. The removal of vegetation in coastal areas, for example, has been linked to several adverse outcomes, such as altered water habitats due to reduced shading and a decrease in the input of organic matter from large trees. Additionally, the absence of vegetation increases nutrient loads, enhances sedimentation, leads to more frequent flooding, and accelerates streambank erosion (Whitman, 2009). These changes not only degrade the quality of the ecosystem but also reduce the ability of the land to perform essential functions, such as filtering pollutants and stabilizing soil.

The primary aim of this study is to assess the current status of the coastal zone along the Andırın River and to evaluate the effects of different vegetation types and land uses on the physical and chemical properties of soils within the coastal zone. For this purpose, soil samples were collected at distances of 2, 10, and 25 meters from both sides of the main branch and tributaries of the Andırın River. The collected samples were analyzed for various physical and chemical properties, such as soil texture, aggregate stability, hydraulic conductivity, and nutrient content, to better understand how land use practices impact soil health in this region.

This research is expected to contribute valuable insights into the management of riparian zones, highlighting the importance of preserving natural vegetation and implementing sustainable land use practices to protect soil and water resources. In light of the findings, recommendations for future conservation and management strategies will be provided to ensure the continued functioning of these critical ecosystems.

MATERIAL AND METHODS

Study Area

The Andırın River is situated in the southwestern part of Kahramanmaraş province in southern Turkey (Figure 1a). The river, along with its tributaries, classified between 1st and 5th order according to the Strahler stream order system, has a total length of 372 kilometers. The basin area spans 21,180 hectares, encompassing a diverse range of landscapes and ecosystems.

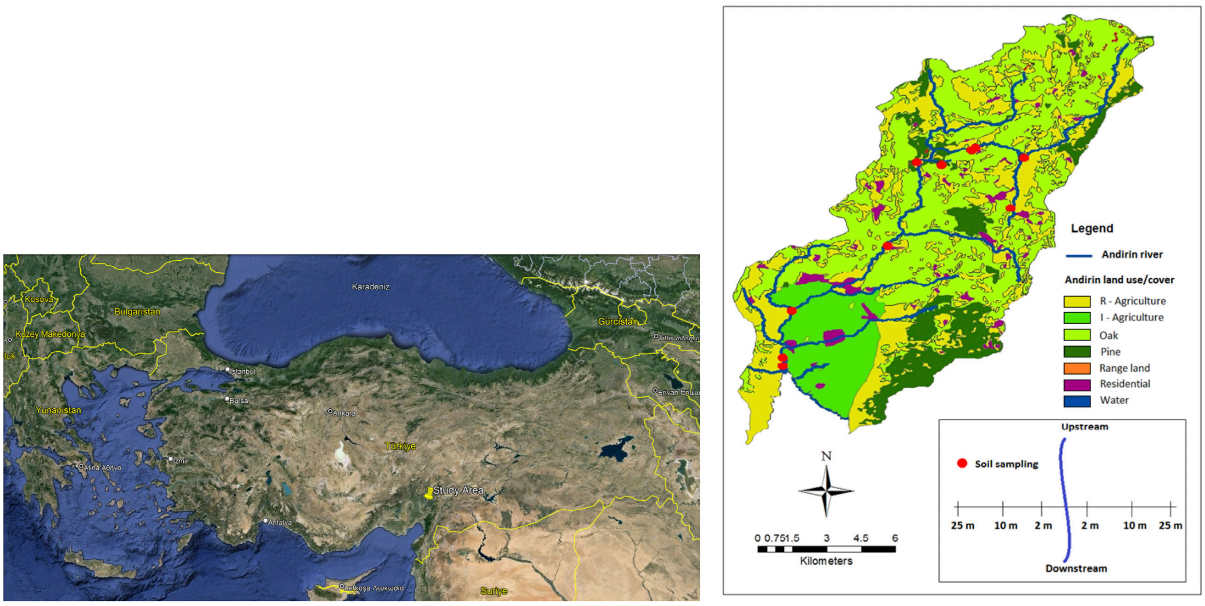

Figure 1. Location of the study area

The Andırın River basin experiences a Mediterranean climate characterized by dry summers. Long-term meteorological data (1960–2013) indicate that the coldest month is January, with an average temperature of 4.8°C, while the hottest month is August, averaging 28.4°C. The annual mean temperature is 16.8°C. Although precipitation is distributed throughout the year, it is concentrated in the winter months and reaches its lowest levels during the summer. The long-term annual average precipitation is 745 mm (MGM, 2015). The river's flow rate typically peaks between November and April due to storms and heavy rainfall. The basin, for the most part, is well-drained, with the exception of a few low-lying areas.

Geologically, the Andırın River basin is composed of various formations dating back to the Jurassic-Cretaceous period, including ophiolite, schist, dolomitic limestone, and basic volcanic rocks. Other formations consist of Miocene-Pliocene limestone, sandstone, gravel, fine-grained marl sequences, and Quaternary alluvial deposits (MTA, 1975; Kozlu et al., 1978). The primary soil types in the basin include brown forest soils with dark-colored surface horizons, Terra Rossa soils predominantly found in the western regions, and colluvial soils with loose, complex textures, typically present on foot slopes. Alluvial soils dominate the lower parts of the basin. Terra Rossa soils, formed over limestone, are characterized by clay textures and good aggregate stability (KHGM, 1981).

Land use in the Andırın basin is primarily forest and agricultural land. Oak and pine forests dominate the region, especially in the central and northern parts of the basin, covering more than half of the total land area (OGM, 2003). Rainfed agricultural lands are scattered throughout the basin, while irrigated agricultural lands are more concentrated in the southern regions.

Soil Analysis

To analyze the effects of land use on the physical and chemical properties of soils in the riparian zones of the Andırın River, soil samples were collected from nine different locations along the river and its tributaries. These samples were taken at three distinct distances from the river on both sides: 2 meters, 10 meters, and 25 meters. Samples were also collected at two soil depths: 0-10 cm and 10-20 cm. In total, 93 soil samples were collected (see Figure 3.4 for sampling points). The samples were air-dried, ground, and passed through a 2 mm sieve for analysis. The physical properties analyzed included particle size distribution (Gee and Or, 2002), aggregate stability (Nimmo and Pekins, 2002), and hydraulic conductivity (Klute and Dirksen, 2002). In addition, chemical properties such as organic matter content, pH (Mclean, 1982), total salinity (Rhoades, 1982), carbonate content, available potassium (Knudsen et al., 1982), and phosphorus (Olsen and Sommers, 1982) were determined.

Statistical Analysis

All collected data were recorded in an Excel spreadsheet for analysis. To evaluate the physical and chemical properties of soils under different land use types, the data were analyzed using SPSS18 software. Duncan's multiple comparison test was employed to compare the means between the different land uses and distances from the river, allowing for a clear evaluation of the effects of land use on soil characteristics.

RESULTS AND DISCUSSIONS

The physical and chemical properties of soils at three different distances (2 meters, 10 meters, and 25 meters) from the Andırın River were analyzed for four different land uses: oak forest, pine forest, irrigated agriculture, and rainfed agriculture (Table 1, 2 and 3). These results reveal clear differences in soil texture, aggregate stability, hydraulic conductivity, organic matter, and nutrient content between the land uses and distances from the river.

Soil Texture and Particle Distribution

Across all distances, the soil texture was primarily sandy loam, with a tendency for higher sand content in soils near the river. At the 2-meter zone (Table 1), irrigated agricultural land exhibited the highest sand content (88.49%), significantly higher than oak (83.58%) and pine forests (81.21%), while rainfed agriculture had the lowest sand content (74.11%). As the distance from the river increased, sand content decreased slightly in irrigated agricultural soils, while in forested areas it remained relatively stable. At the 25-meter zone (Table 3), the highest sand content was still found in irrigated agricultural land (76.63%), while oak forest soils showed the lowest (69.38%).

The high percentage of sand observed along the riverbanks is largely attributed to the region's steep topography and geomorphological characteristics. The Andırın River basin is marked by steep and very steep slopes, which facilitate the transport of coarse soil particles from the upland areas to the river via surface runoff and small tributaries. This variation in sand content can be attributed to land use practices and topographical influences. Coarse sand particles are more likely to accumulate near riverbanks due to the deposition of materials carried by surface runoff.

The primary reason for the variation in particle size observed over short distances in the study area is sedimentation during river floods. In this horizontal sedimentation process, heavier coarse particles are deposited near the river, while finer particles are carried to and deposited at farther distances where the water can reach (Günal, 2006). Irrigated agricultural practices, which disturb the soil and involve the movement of water, likely exacerbate the accumulation of sand. On the other hand, forested areas, particularly oak forests, retain finer soil particles due to better ground cover and reduced soil disturbance, thus showing higher clay content in the 10-meter and 25-meter zones.

The process of coarse material transport is primarily driven by surface runoff from the steep slopes, which erode and carry larger soil particles, such as sand, toward the river. This phenomenon has been observed in similar studies; for instance, Ufot et al. (2016) demonstrated that steep terrain contributes to sand accumulation in riparian areas while decreasing the content of finer particles like clay and silt. Consequently, soils near riverbanks tend to have a higher sand content, a finding that is consistent with the results of the current study.

Table 1. Effects of land use on soil properties in the 2-meter zone

Soil Properties	Oak	Pine	Irrigated Agriculture	Rainfed Agriculture
Sand (%)	83.58 bc	81.21 b	88.49 c	74.11 a
Silt (%)	8.97 a	9.27 a	6.64 a	9.80 a
Clay (%)	7.43 ab	9.50 b	4.86 a	16.07 c
Aggregate Stability (%)	41.40 ab	59.93 b	38.70 a	50.26 ab
Hydraulic Conductivity (cm/h)	3.87 ab	5.64 b	3.22 a	2.77 a
Organic Matter (%)	2.55 a	3.34 a	1.95 a	2.05 a
pH (H2O)	8.06 ab	8.0 ab	7.9 a	8.17 b
EC (µmhos/cm)	280.38 a	338.29 a	357.31 a	298.73 a
CaCO3 (%)	31.0 b	13.9 a	32.27 b	11.7 a
K (mg/kg)	140.2 a	126.0 a	84.4 a	140.4 a
P2O5 (mg/kg)	4.06 a	3.86 a	5.30 a	12.6 b

*Mean values followed by the same letters in a column are not significantly different ($p \leq 0.05$)

In contrast, flat areas adjacent to rivers are more conducive to the deposition of finer particles, such as silt and clay, as the lower gradient slows down water flow, allowing these finer materials to settle. However, in regions like Andırın with pronounced slopes, coarse materials dominate the riverbanks. This pattern is corroborated by Niknahad and Maramaei (2011), who also observed significant variations in soil texture between forested and agricultural lands in similar environments. Their findings indicated that agricultural lands often have a finer soil texture compared to forested areas, further emphasizing the role of land use and topography in shaping soil characteristics in riparian zones.

Overall, the geomorphological and hydrological processes in the Andırın River basin contribute to the distinct soil textures observed at varying distances from the river, with sandy textures prevailing near the riverbanks due to the continuous deposition of coarse materials from the surrounding steep slopes.

Aggregate Stability

The results demonstrate that land use significantly influences aggregate stability, particularly in forested areas. In the 2-meter zone (Table 1), pine forest soils showed the highest aggregate stability (59.93%), significantly higher than irrigated agricultural soils (38.70%). Aggregate stability remained higher in forested areas at all distances, with pine and oak forests showing consistently strong stability across the 10-meter and 25-meter zones. In the 25-meter zone (Table 3), pine forest soils maintained high aggregate stability (72.40%), similar to oak forest soils (73.50%).

Soils under pine forests exhibited higher aggregate stability compared to other land uses, whereas no significant differences were observed between irrigated and rainfed agricultural soils. This high aggregate stability in forest soils is likely due to the greater organic matter content and less soil disturbance compared to agricultural areas. The presence of tree roots and organic material in forested areas promotes the formation of stable aggregates, which helps reduce erosion and maintain soil structure. The low organic matter content in agricultural soils is likely the main factor contributing to the reduced aggregate stability (Karimi et al., 2008). The use of agricultural machinery and the repeated disturbance of the soil through tilling break down large soil aggregates, exposing organic matter to microbial decomposition and oxidation, which accelerates organic matter loss. Land-use changes, particularly those involving agriculture, can lead to soil degradation and a reduction in organic matter content, which negatively impacts aggregate stability and increases the risk of erosion over time (Ataollah et al., 2014). Erosion processes, especially in steep areas, transport finer particles such as silt and clay downslope, leaving coarser particles like sand behind. This selective transportation further alters soil texture and decreases the soil's capacity to retain water and nutrients.

Continuous tillage disrupts the natural aggregation process, preventing the formation of stable soil aggregates and resulting in weaker soil structures (Gholami et al., 2016). Similarly, Mainuri and Owino (2013) reported significant differences in aggregate stability across various land uses, with forested areas demonstrating much higher stability due to higher organic matter content. They suggested that the reduced stability in agricultural soils was mainly attributable to tillage practices. Likewise, Khormali et al. (2009) found that the breakdown of large aggregates in agricultural lands, coupled with organic matter loss due to intensive farming, led to lower aggregate . Similarly, Çelik (2005) showed that aggregate stability in forest soils was significantly higher compared to agricultural soils.

Table 2. Effects of land use on soil properties in the 10-meter zone

Soil Properties	Oak	Pine	Irrigated Agriculture	Rainfed Agriculture
Sand (%)	76.1 ab	74.9 ab	80.0 b	70.7 a
Silt (%)	11.7 b	4.9 a	13.3 b	10.6 b
Clay (%)	12.2 b	13.9 bc	6.8 a	18.7 c
Aggregate Stability (%)	59.9 ab	76.7 b	55.7 a	40.2 a
Hydraulic Conductivity (cm/h)	4.42 b	4.96 b	2.7 a	2.71 a
Organic Matter (%)	3.8 ab	4.9 b	2.4 a	1.9 a
pH (H2O)	8.0 c	7.8 ab	7.8	8.0 bc
EC (µmhos/cm)	325.3 a	284.0 a	254.9 a	500.3 a
CaCO3 (%)	33.8	12.6 a	26.5 b	4.6 a
K (mg/kg)	308.3 a	181.8	277.1 a	102.6
P2O5 (mg/kg)	3.64 a	5.92 a	7.99 a	18.13 b

*Mean values followed by the same letters in a column are not significantly different ($p \leq 0.05$)

Hydraulic Conductivity

Hydraulic conductivity varied significantly across land uses, with forested areas showing higher conductivity than agricultural lands. No significant differences were found between irrigated and rainfed agricultural soils, but soils under oak and pine trees exhibited significantly higher hydraulic conductivity. In the 2-meter zone (Table 1), pine forest soils exhibited the highest hydraulic conductivity (5.64 cm/h), while irrigated agricultural soils had the lowest (3.22 cm/h). This trend continued in the 10-meter and 25-meter zones, with pine forest soils consistently demonstrating higher hydraulic conductivity compared to agricultural soils. At the 25-meter zone (Table 3), pine forest soils had a hydraulic conductivity of 6.40 cm/h, more than double that of rainfed agricultural soils (2.84 cm/h)

The highest hydraulic conductivity was observed in soils under pine trees, which was approximately double that of the agricultural soils. The higher hydraulic conductivity in forested areas can be attributed to better soil structure and porosity, enhanced by root systems that create channels for water movement. The minimal disturbance in forested areas, where decaying tree roots contribute to the formation of soil pores and channels, enhancing water infiltration. In contrast, the low hydraulic conductivity in agricultural lands can be linked to the compaction of soil pores caused by heavy machinery and continuous tillage practices. These findings align with previous studies showing that forests generally have better water permeability compared to intensively managed agricultural lands (Jie et al., 2017). Karimi et al. (2008) further noted that soil crust formation, caused by the breakdown of aggregates, reduces soil permeability. Moreover, Wahren and Feger (2010) demonstrated that hydraulic conductivity in forested areas can be twice as high as in agricultural lands, largely due to decaying tree roots creating natural channels in the soil, which improve water movement and increase organic matter content.

Table 3. Effects of land use on soil properties in the 25-meter zone

Soil Properties	Oak	Pine	Irrigated Agriculture	Rainfed Agriculture
Sand (%)	69.38 a	72.42 ab	76.63 b	69.17 a
Silt (%)	9.76 a	13.25 b	12.57 ab	10.33 ab
Clay (%)	20.85	14.32	10.78 a	20.49 b
Aggregate Stability (%)	73.50 b	72.40 b	44.99 a	66.43 b
Hydraulic Conductivity (cm/h)	4.68 ab	6.40 b	2.93 b	2.84 a
Organic Matter (%)	48.7 b	29.5 a	24.3 a	28.9 a
pH (H2O)	7.9 a	7.9 a	8.0 a	7.7 a
EC (µmhos/cm)	242.5 a	346.6 a	461.5 a	503.2 a
CaCO3 (%)	27.65 b	21.78 b	25.58 b	22.75
K (mg/kg)	170.01 a	212.43	128.69 a	137.31 a
P2O5 (mg/kg)	3.43 a	3.33 a	6.81 a	13.09 a

*Mean values followed by the same letters in a column are not significantly different ($p \leq 0.05$)

Organic Matter and Soil Nutrients

Organic matter content varied considerably across land uses but showed no significant changes with distance from the river. In the 2-meter zone (Table 1), pine forest soils had the highest organic matter content (3.34%), while irrigated agricultural soils had the lowest (1.95%). This pattern was consistent across all distances, with forest soils maintaining higher organic matter levels compared to agricultural soils. In the 25-meter zone (Table 3), oak forest soils had the highest organic matter content (48.7%), while irrigated agricultural soils again had the lowest (24.3%). The higher organic matter content in forest soils can be attributed to the continuous input of organic residues from vegetation, such as leaves and roots, which decompose and enrich the soil. In contrast, agricultural soils, particularly those under intensive irrigation, tend to lose organic matter due to tillage, erosion, and oxidation processes. The reduction in organic matter in agricultural soils can lead to poorer soil structure, reduced water retention, and lower fertility over time. In broader studies, Guo and Gifford (2002) reported that organic matter concentrations can vary significantly up to 100 cm depth depending on factors such as land use, vegetation cover, and climate. However, in surface layers, organic matter tends to accumulate, with a net increase observed in the upper soil profile, making the soil an effective carbon sink that contributes to the reduction of CO2 emissions (Bayer et al., 2000).

Regarding nutrients, phosphorus (P2O5) content varied significantly among land uses. In the 2-meter zone (Table 1), rainfed agricultural soils had the highest phosphorus content (12.6 mg/kg), while pine forest soils had the lowest (3.86 mg/kg). This trend persisted across the other distances, with agricultural lands generally showing higher phosphorus levels, possibly due to fertilizer application. Potassium (K) levels were adequate for all land uses, with no significant differences observed between the different distances.

The soil pH values across all land uses and distances from the river indicated an alkaline environment, with pH levels ranging between 7.7 and 8.17. In the 2-meter zone (Table 1), rainfed agricultural soils had the highest pH (8.17), while irrigated agricultural soils had the lowest (7.9). These pH values remained relatively consistent across the 10-meter (Table 2) and 25-meter (Table 3) zones, with slight variations between land uses. The relatively high pH levels in the study area suggest that the soils are influenced by the underlying geology, particularly limestone formations, which tend to increase alkalinity. Alkaline soils can impact nutrient availability, particularly micronutrients like iron, zinc, and manganese, which are less soluble and therefore less available to plants in high pH conditions. However, the pH levels observed in this study are typical of Mediterranean climates and are not expected to significantly hinder plant growth, provided that appropriate nutrient management practices are in place.

Carbonate content was also consistently high across the study area, reflecting the limestone-dominated geology of the Andırın River basin. In the 2-meter zone (Table 1), carbonate content was highest in irrigated agricultural soils (32.27%) and oak forest soils (31.0%), while pine forest and rainfed agricultural soils had significantly lower carbonate levels (13.9% and 11.7%, respectively). This trend persisted in the 10-meter zone (Table 2), where irrigated agriculture continued to show elevated carbonate levels (26.5%), whereas rainfed agriculture and pine forest soils exhibited lower values. The high carbonate content is characteristic of soils in regions with significant limestone deposits, such as the Andırın basin. Soils with high carbonate levels tend to have a higher buffering capacity, which helps maintain stable pH levels. However, excessive carbonate can sometimes reduce the availability of certain nutrients, particularly phosphorus, by binding with it and forming insoluble compounds. This may explain the slightly lower phosphorus availability in some zones, particularly in forested areas where carbonate content is lower. Overall, the high carbonate content and alkaline pH of the soils in the Andırın River basin are typical of Mediterranean environments with limestone bedrock (Torrent, 2005). While these conditions support soil stability, they may require careful nutrient management, particularly in agricultural areas, to ensure optimal nutrient availability for crops.

These results highlight the influence of land use and management practices on soil physical and chemical properties, particularly in riparian zones. Forested areas, especially those under pine cover, showed greater resilience in maintaining soil structure and hydraulic properties, while agricultural lands exhibited signs of degradation, likely due to intensive cultivation and mechanization.

CONCLUSION

This study aimed to evaluate the impact of different land use types on certain physical properties of soils in the Andırın river region in southeastern Turkey. Four land use types were considered: oak forest, pine forest, irrigated agriculture, and rain-fed agriculture.

The findings of the study show that soil particle size is only slightly affected by different land use types. The most notable differences in particle size were found between irrigated agriculture and other uses. Soil samples taken along a 2-meter transect showed distinct differences compared to other lengths. Soils at the 2-meter distance contained less clay and silt and more sand compared to other locations. These distance-dependent changes in sand content may reflect geomorphological processes such as gravel accumulation and floodwaters from the river. This suggests that geomorphological processes may obscure the effects of land use/land cover.

The soil aggregate stability in the study area is low, particularly in agricultural lands, which may be due to the breaking and fragmentation of large aggregates caused by agricultural machinery and soil cultivation. This low aggregate stability indicates unsustainable soil use in the study area. Examination of soil aggregate stability at three predetermined lengths according to land use types provided clear information on the stability of soil aggregates under different land use types in the riverbank region. The results show that irrigated agricultural lands have low aggregate stability at all selected lengths, while soils under pine forests are more stable at the specified lengths. Additionally, the aggregate stability of soils under oak forests and rain-fed agricultural lands appears nearly similar at all lengths.

On the other hand, the hydraulic conductivity of soils under rain-fed agricultural lands differs from that under pine forests. The soils in agricultural areas have lower hydraulic conductivity, indicating significant differences in hydraulic conductivity among these selected land uses. This may be due to soil cultivation and the use of heavy machinery in agricultural areas.

The results of chemical soil analysis indicate that land use did not significantly affect any soil properties in the coastal zone region.

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ABSTRACT

A Technique for Regenerative Agriculture in a Southeast Turkish Almond Grove

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Introduction & Purpose: Despite the persistence of natural agricultural practices in many regions post-settlement, inefficient land utilization led to complications that ultimately contributed to the decline of numerous ancient civilizations. The salinization of soils in Mesopotamia from historical over-irrigation, together with the degradation of 75% of the world's agricultural soils of varying scales now, exemplify detrimental consequences of human agricultural practices. Water collecting was implemented in almond orchards to enhance soil moisture and organic carbon as part of regenerative agriculture. Farmers, legislators, and scientific researchers received the results of field observations and laboratory data used to assess the practice's efficacy.

Material and Method: The study was performed in a 12-year-old almond orchard located in Adıyaman, situated in the semi-arid climate zone of southeastern Turkey, during the years 2021 and 2022. Soil samples were collected prior to and during the treatment from beneath the canopies of both treated and untreated trees, at depths of 0–20 cm and 20–60 cm, to assess soil moisture content. Soil samples were examined for pH, texture, organic carbon, electrical conductivity (EC), bulk density, organic matter, and lime content. Crescent-shaped stone benches, about 30-40 cm in height and 3 meters in length, were constructed for water gathering in October 2021, utilizing 20-30 cm diameter stones sourced from local marble quarries before the onset of rainfall.

Findings & Conclusion: The organic matter value of the almond orchard was far below the acceptable amount of 4% (>2% organic carbon) for agricultural soils. The most recent measurement of soil moisture content was conducted in October 2022, revealing a considerable increase in the water harvesting research utilizing waste marble stones, with a recorded level of 12.6 tons per hectare at a depth of 0-60 cm, compared to untreated areas. The average gain was 4.2%. Due to the prolonged response time of soil organic

matter to treatments, no change in organic matter was seen within a year. This study demonstrated that restorative agricultural practices, even at minimal levels, yielded rapid and advantageous outcomes in damaged soils. It is essential to ensure that regenerative agriculture practices incorporate cost-effective investment strategies for farmers facing recent increases in production expenses. The enhancement of soil moisture content by the utilization of entirely natural marble stones, devoid of heavy metals or hazardous substances while being byproducts of rock mining, exemplifies successful regenerative agriculture in this context.

Keywords: Regenerative agriculture, almond, Southeastern Türkiye, water harvesting

Acknowledgement: Authors would like express their profound thanks to Silkroad Development Agency for funding the "Regenerative Agriculture and TRC 1 Region" project

Farm-Based Applicatıon of Rejeneratıf Agricultural Techniques Aydın Province Söke District Example

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Introduction & Purpose: Protective soil management for the improvement of soil health and sustainability of production has started to be adopted especially in developed countries such as European countries.

Material and Method: The study was carried out in traditional and cover crop, direct sowing cotton cultivation application for 4 years in 58 decare area in Efeler Farm of Söke District of Aydın Province. In the study where two different doses of chemical fertilizer were applied, 1 ton/da organic fertilizer was applied every year. Sorghum was planted as cover crop in the first year. Then, winter vetch, pea, triticale and animal beet mixture was planted for two years and rye mixture was planted instead of triticale in the same mixture in the last year. The planted cover crops were broken with a crimper tool in April-May and the withering process was carried out. 10-12 days after the withering process was completed, the soil was provided with a central pressurized irrigation system to provide suitable tempering for planting and cotton was planted. After the cotton harvest each year, disturbed and undisturbed soil samples were taken from 0-15, 15-30 and 30-45 cm depths from 10 different points and texture, bulk density, field capacity, wilting point, available moisture content, % organic carbon, organic carbon stock calculation, total pore, macro and micro pore volume analyses were carried out.

Findings & Conclusion: The results obtained from the analyses carried out at the end of the total 4-year applications showed that the bulk density was high at 15-30 and 30-45 cm depths all of the sampling points. Total pore volumes were found to be below the ideal value at the surface and subsurface at all points. Organic carbon stocks were found to be lower in the soils where chemical fertilizer was applied. Total available water content was found to be 65.81 mm in the traditional application

Keywords: Rejeneratif agriculture, no-till, soil properties

The Effects of Ecosystem-Based Regenerative Agriculture Practises on Some Soil Properties in the Çifteler District of Eskişehir Province

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Introduction & Purpose: This study was designed based on the assumption that organic inputs would lead to greater microbial diversity and a microbial community, and that the combination of cover crops, no-till farming, and organic inputs would maximize soil microbial diversity and consequently the soil's organic carbon content.

Material and Method: In this context, long-term (5-year) field experiments were conducted in the Çifteler district of Eskişehir around 5.5 ha. Some biological sensitive indicators were determined to estimate the impact of conservation agriculture practices on the soil quality parameters.

Findings & Conclusion: The results indicated that soils under conservation agriculture had significantly higher values of total N, organic carbon, microbial biomass carbon, basal soil respiration, and catalase enzyme activity compared to soils managed under traditional agricultural practices. In dry farming, the highest qCO2 values were observed with extract application, while in irrigated conditions, qCO2 values were lower in conservation agriculture practices. C mineralization in dry farming was 185.2-235.4% in reference soils, whereas it was 37.1-86.0% in non-extract treated soils and 22.9-37.1% in extract-treated soils under conservation agriculture. In irrigated farming, C mineralization was 32.8-84.2% in reference soils and 48.0-58.3% in conservation agriculture soils. Catalase enzyme activity was higher in soils under conservation agriculture than in reference soils under both dry and irrigated conditions. In dry conditions, reference soils had catalase activity values of 22.9-52.1, while extract-treated soils had 86.0-235.4 ml O2/g. In irrigated conditions, reference soils showed catalase activity values of 366.8-668.8, whereas conservation agriculture soils had 454.7-875.0 ml O2/g. The combination of conservation agriculture and extract applications have increased soil microbial activities compared to traditional tillage. These results indicated that effective management through reduced tillage, the inclusion of cover crops in the cropping system, and the increased input of extracts and other organic carbon sources can enhance soil microbial diversity and the soil's carbon pool.

Keywords: Carbon, compost extract, enzyme activity, mineralization, regenerative agriculture

The Impact of Regenerative Agriculture on Soil Organic Carbon and Climate Change

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Introduction & Purpose: Regenerative agriculture aims to reduce the amount of carbon dioxide released into the atmosphere by increasing the soil's organic carbon content. Therefore, regenerative agriculture is an agricultural approach that not only improves farm profitability and soil health but also plays a significant role in combating climate change.

Material and Method: The fundamental principles of regenerative agriculture include maintaining soil cover, minimizing soil disturbance, increasing plant diversity, integrating livestock, and reducing the use of synthetic compounds. These practices help reduce soil erosion while allowing the soil to store organic carbon for longer periods. Cover crops and residue retention methods help protect the soil surface and allow plant roots to penetrate deeper into the soil. Additionally, they enhance microbial activity in the soil, creating a more efficient and sustainable ecosystem. Research indicates that regenerative agriculture practices can enhance soil carbon, crop yields, and overall soil health in specific climate zones and soil types. However, the effectiveness of these practices may vary across different agricultural ecosystems. Therefore, to fully understand the potential of regenerative agriculture, long-term farming system trials and the development of strategies tailored to local conditions are necessary.

Findings & Conclusion: This study aims to provide a general perspective on the effects of regenerative agriculture practices on soil organic carbon and climate change. Consequently, regenerative agriculture is a significant tool in combating climate change by improving soil health and reducing carbon dioxide emissions from the soil through organic carbon sequestration. This approach, with the widespread adoption of regenerative agriculture, can help mitigate the adverse effects of climate change by enhancing soil health and increasing the resilience of agricultural ecosystems.

Keywords: Climate change, carbon dioxide, regenerative agriculture, soil organic carbon

The Effects of Different Forms of Maize Straw on LLWR and Soil Physical Properties in Agricultural Lands

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Introduction & Purpose: In recent years, the increase in soil compaction due to increasing field traffic and lack of organic matter in agricultural lands has had a detrimental impact on the capacity of plants to utilize soil water. The irregular precipitation patterns associated with global warming and the increased frequency of droughts in arid and semi-arid regions have prompted the search for solutions to the challenges posed by water scarcity and water storage.

Material and Method: Accordingly, the present study sought to examine the impact of maize straw (at concentrations of 1, 2, and 4%), maize compost, and maize green parts on soil water content, a variable known as LLWR. In this study, undisturbed soil samples were obtained from a depth of 0-20 cm following the harvesting of the maize plant, and penetration measurements were conducted on the field. The effects of soil compaction were evaluated through the measurement of bulk density and penetration resistance on soil samples.

Findings & Conclusion: The study's conclusions led to the determination of the LLWR values. Even though LLWR rises with higher treatment dosages, compost applications have produced the greatest results of all the applications. The findings demonstrate that the utilization of diverse forms of maize straw, which is often a challenge to dispose of, represents an effective approach for enhancing soil physical properties in agricultural settings. It is therefore evident that organic matter applications represent a crucial strategy for the sustainable management of agricultural lands.

Keywords: Least limiting water range, organic matter, soil compaction

Determining the Land Degradation and Temporal Changes of Bursa Province Using CORINE Erosion Model

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Introduction & Purpose: Many factors such as misuse of lands, industrialization, rapidly population growth, soil erosion, pollution are among the factors that threaten our natural resources in our country and in the world. Preventing or reducing the negative effects of these threats primarily depends on determining and observing the quality and quantity of our natural resources. In recent years, remote sensing and geographic information systems have become accurate, fast, economical and widely used tools in data production and observation of natural resources.

Material and Method: In this study, it is aimed to evaluate the erosion risk in Bursa province lands by using CORINE land use/cover data (1990-2018), to identify and map the risky areas in a GIS environment, and to present the precautions to be taken. In addition, the negative effects of land use/cover changes that occurred between 1990-2018 on the natural resources of Bursa Province and to areas with high erosion risk were also determined and the results were discussed.

Findings & Conclusion: According to the results, 78% of Bursa Province lands (837080.4 ha) has medium and high potential erosion risk due to soil, topography and climatic conditions. On the other hand, 15.2% (163320 ha) of the lands has low potential erosion risk. When the potential erosion risk classes and vegetation cover are examined on the actual erosion risk maps created for 1990 and 2018, there was a decrease of 2.5% in the low erosion risk class and 7.9% in the medium erosion risk class, and an increase of 10.4% in the high erosion risk class due to degradation of forests and semi-natural vegetation areas. Through the studied years (1990-2018), it was determined that there was an increase of 23.547 ha in artificial areas, and a significant decrease of 9.027 ha in agricultural lands, and 16.124 ha in forest and semi-natural areas.

Keywords: Land cover, changes, CORINE erosion model, GIS, erosion risk

An Influence of Land use Change on Water Resources in the Central Rift Valley Sub-basins in Ethiopia

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Introduction & Purpose: This study has aimed to analyze past and predicted LULC dynamics and their impacts on the components of the water balance in the Central Rift Valley (CRV) sub-basins in Ethiopia. The Soil and Water Assessment Tool (SWAT) and the Land Change Modeler (LCM) were employed to evaluate the impacts of past and future LULC dynamics in the Ketar, Meki and Shalla sub-basins. The SWAT models were calibrated with flow data from 1990 to 2001 and were validated with flows from 2004 to 2010, using SWAT-CUP in the SUFI-2 algorithm. LCM with Multi-Layer Perceptron (MLP) neural network method for land transition scenario analysis and a Markov Chain method for predictions, as well as SWAT models with fixing-changing methods for simulations, were used to evaluate the condition of hydrological processes under the influence of changes in LULC

Material and Method: The study area CRV is located in the East Africa region, in the upper head of the rift valley basin in Ethiopia. Geographically, the basin area extends from 38°15’00” E and 39°27’0” E to 7°00’0”N and 8°30’00” N and covers an area of 15,301.96 km2. The SWAT models were calibrated with flow data from 1990 to 2001 and were validated with flows from 2004 to 2010, using SWAT-CUP in the SUFI-2 algorithm. LCM with Multi-Layer Perceptron (MLP) neural network method for land transition scenario analysis and a Markov Chain method for predictions, as well as SWAT models with fixing-changing methods for simulations, were used to evaluate the condition of hydrological processes under the influence of changes in LULC.

Findings & Conclusion: The analyses resulted in an annual runoff variation from − 20.2 to 32.3%, water yield from − 10.9 to13.3%, and evapotranspiration from − 4.4 to 14.4% in the sub-basins, due to changes in LULC. Integrated land use planning is recommended for the management of water resources.

Keywords: Soil hydrologic processes, land use and land cover, integrated land use planning, land change modeller

Arsenic Water Issue in Cappadocia (Nevşehir): General Evaluation

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Introduction & Purpose: In Turkey, which is located in the Alpine-Himalayan tectonic formation zone, intense arsenic pollution is observed in underground waters due to special hydrogeochemical factors in geothermal resources such as Afyonkarahisar, Simav, Kozak, Balçova, boron mining areas in Kütahya Emet and Nevşehir region as a result of multi-fracture structure and volcanic activities. Geological studies have recently shown that arsenic levels in drinking water ranged from 11 to 500 µg/L in Nevsehir province, Turkey. The maximum limit value for As drinking water in Turkey is 10 µg/L. Possible health problems in individuals living in the region due to chronic arsenic exposure were investigated in detail at Gazi University Health Sciences Institute. Accumulation of arsenic in confectionary pumpkin seeds and five different types of vegetables was also studied in the region. The main purpose of this study is to draw attention to the problems of arsenic in drinking and irrigation water still used in the region

Material and Method: Latest publications on the health and agriculture due to the use arsenic-rich waters in the region is reviewed

Findings & Conclusion: Gazi University pointed out that inhabitants of Dadağı, Küçükayhan, Emmiler, and Gülpınar villages consuming arsenic-rich waters >50µg/L, have higher levels of arsenic in hairs and urine samples than controls indicating chronic arsenic exposure. No significant increase was observed in the frequency of skin lesions. However, due to the increased genotoxicity risk, cancer registry activities in the region are highly recommended. Arsenic levels in the soil, irrigation water, and products where five different types of vegetables were grown were also found to be above the limit values given on these issues. For sustainable arsenic treatment and to provide water supply with acceptable arsenic levels in the region, mobile technical control teams must be formed and operated under the Governor of Nevşehir Province Special Administration and Regional Development Agencies.

Keywords: Nevşehir, arsenic, health aspects, agriculture

Assessment and Management of Agricultural Soil Diffuse Pollution in Serbia

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Introduction & Purpose: Agricultural soil pollution is primary caused by improper use of plant protection chemicals (PPCs), fertilizers and plastics, but also polluted soils are secondary source of pollution. Consequences are numerous, from the environmental pollution to the effects on the food/feed quality and further potential consequences to human/animal health. Agricultural land in use in Serbia covers 3.488.752 ha, 44.96% of the country area, with 75.54% of arable and garden soils but there is only limited number of studies investigated diffuse soil pollution.

Material and Method: In order to assess the effect of the agricultural activities on soil, the research study on agricultural soils, on three sensitive locations close to lakes/protected areas (Palić-Ludoš, Bajina bašta, Gruža) was done, in cooperation of the FAO and national Environmental Protection Agency and engaged few research institutions. Samples of soils, underground and irrigation water and organic fertilizers are collected and numerous parameters are analyzed (soil physical and chemical properties, PTEs and organic pollutants) according to proposed methodology.

Findings & Conclusion: The study reveals that some of the pollution-problems are caused by natural factors, e.g. concentration of PTEs in soil, particularly in deeper soil layers, but the others are related to agricultural activities e.g. improper manure storage and improper use of pesticides, specially in the past (e.g. DDT). In order to improve management of

the agricultural soils, continuous education of farmers and agricultural advisory service through different trainings related to proper use of PPCs and fertilizes (organic/mineral) and proper storage, is important. Support of government to farmers to get better manure storage facilities is needed. On the soils with the higher concentrations of PTEs than limit vales (remediation values are not exceeded), continuous monitoring of soil and plants are needed according to the national regulations. Increase of areas under organic agriculture will also decrease a risk.

Keywords: Indicators, nitrates, phosphorus, pesticide residues, PTEs

ARBio Project: International Collaborative Research on Globally Unique Alkaline Paddy Field Soils in Türkiye

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Introduction & Purpose: Türkiye ranks as the third-largest rice producer in Europe, with >900,000 tons produced annually from approximately 1.16 million hectares of paddy fields. The soil pH in Türkiye is generally high, often exceeding pH 8. Alkaline soils are widely distributed in arid regions. However, alkaline paddy fields are rare worldwide except in Türkiye and some parts of China because there is a climatic unsuitability for managing paddy fields, which require large amounts of irrigation water. Previous studies on Turkish paddy field soils have primarily focused on the physicochemical properties related to rice productivity. Although exploring microbial diversity and fully utilizing its functions for sustainable rice production are both important, only a few studies have been available for alkaline soils in Türkiye. Information on biogeochemical cycles is also lacking, particularly concerning greenhouse gas emissions. Therefore, we, Turkish and Japanese soil scientists, launched a new international collaboration research project in 2023, the "ARBio Project" meaning the Alkaline Rice paddy microBiology Project, under the support of JSPS Kakenhi.

Material and Method: The ARBio Project aims to elucidate the characteristics and functions of rice rhizo-microbiota (bacteria, archaea, and protozoa) and understand soil carbon and nitrogen dynamics, particularly greenhouse gas emissions, focusing on the alkaline (+saline) paddy fields in Türkiye. Therefore, focusing on alkaline paddy soil, we plan to conduct field surveys, rice pot cultivation experiments, and soil microcosm studies to elucidate the relationships among rice productivity, soil physicochemical properties, and rhizosphere microflora, to understand the role of soil- and rhizo-microbiota in alkaline paddy fields, and to evaluate the characteristics of organic matter and greenhouse gas emissions.

Findings & Conclusion: Many students and young researchers will participate in the ARBio Project, which will also contribute to the next generation's cooperation between Japan and Türkiye in soil science.

Keywords: Alkaline paddy fields, greenhouse gas emissions, soil microbiota

Importance of Organic Matter in the Microbial Carbon Cycle

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Introduction & Purpose: Soil microbial carbon is a critical component for the sustainability and productivity of soil ecosystems. Microbial carbon refers to the biomass of microorganisms living in soil, and these microorganisms play a central role in the processes of decomposition and mineralization of organic matter. Organic matter includes plant and animal remains as well as the biomass of microorganisms themselves. Organic matter added to soil directly affects the amount of soil microbial carbon by increasing microbial activity.

Material and Method: The quantity and quality of organic matter are the main factors determining the amount of microbial carbon. High-quality organic matter contains easily degradable compounds, which allows microorganisms to grow and multiply rapidly. Thus, microbial carbon increases rapidly. On the other hand, low-quality organic matter contains compounds that are more resistant, which slows down the decomposition process of microorganisms, so microbial carbon accumulation is slower.

Findings & Conclusion: As a result, increased soil microbial carbon has positive effects on soil health and fertility. Microorganisms release nutrients during the breakdown of organic matter, increasing nutrient uptake by plants and improving soil structure. Microbial carbon also plays a critical role in the carbon cycle as an important component of soil organic carbon. Sustainable management of soil microbial carbon is of strategic importance to increase productivity in agricultural production and strengthen resilience to climate change. Therefore, organic matter applications and soil management strategies should be carefully planned to increase microbial carbon.

Keywords: Microbial carbon, organic matter, productivity, soil management

Impact of Nano-Silicon Synthesized at Different Reaction Temperatures on Rice Plant Growth and Silicon Uptake

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Introduction & Purpose: Silicon (Si) plays a crucial role in plant growth and productivity, particularly for silicon-accumulating crops such as rice. Nano-sized silicon particles (Nano-Si) have shown greater effectiveness in enhancing silicon bioavailability compared to bulk silicon fertilizers. This study aimed to evaluate the effects of Nano-Si synthesized at different temperatures on the growth and yield of rice plants.

Material and Method: Nano-Si was synthesized at four different reaction temperatures: 300, 500, 700, and 900 °C. The molecular structure and functional groups of Nano-Si was determined using X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FTIR). The effects of Nano-Si produced at different temperatures on the growth and Si uptake of rice plants were tested in both hydroponic and soil systems.

Findings & Conclusion: The different reaction temperatures for the production of Nano-Si influenced the Si concentration of the particles and, consequently, the growth of the rice plants. Nano-Si synthesized at 300 °C showed limited impact on rice plants due to its lower Si content. In contrast, nano-Si synthesized at 500 and 700 °C resulted in higher Si accumulation in the plants, leading to notable improvements in growth and yield parameters. The highest synthesis temperature of 900 °C produced Nano-Si with the maximum Si concentration, resulting in the greatest yield increase. These findings indicate that higher reaction temperatures of Nano-Si enhance Si uptake of rice plants, by positively affecting growth. In conclusion, this study highlights the significant role of reaction temperature in optimizing the effectiveness of nano-Si applications for improving rice growth and Si concentration, offering valuable insights for future agricultural practices and research.

Keywords: Rice, silicon fertilizer, nano silicon

Diversity of Soil-Derived Endophytic Bacteria Associated With Rice Roots

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Introduction & Purpose: Plant endophytic bacteria play an important role in promoting plant growth by producing plant hormones, improving nutrient availability, and directory or indirectly suppressing pathogens. Previous studies have mainly focused on endophytic bacterial communities that are beneficial to the host plant. On the other hand, those that have no apparent effect on plant growth, or those that are not pathogens but negatively affect plant growth, have received little attention.

Material and Method: We used a hydroponic system that prevents root-soil contact to assess the influence of soil-borne endophyte communities on the formation of rice root endophyte communities across the five soil types. We also comprehensively isolated and identified root endophytic bacteria from rice grown hydroponically using andosol or gley lowland soil as the inoculum source.

Findings & Conclusion: Results showed that 16 genera of endophytic bacteria were common across the treatments, but some soil-specific genera were also found. In particular, andosol contributed to the most diverse endophytic community, but rice growth was comparatively poor. In contrast, endophytes derived from gley lowland soil shared most genera with other soils and supported relatively good rice growth. These results suggest that higher richness and diversity of the root endophytic bacteria do not necessarily promote rice growth. Based on morphological characteristics, 154 strains of root endophytic bacteria were isolated and were then identified as 36 species belonging to 19 genera in 6 phyla based on the 16S rRNA gene. In addition, the effects of at least 15 soil-derived endophytic bacterial isolates on the early growth of rice plants have been examined. It is necessary to isolate rice endophytic bacteria from more diverse environments and evaluate their respective effects on rice growth in future studies.

Keywords: Endophytic bacteria, plant-microbe interaction, rice

Evaluating Vermicompost and Rhizobium Synergy on Soil Biology and Chickpea {Cicer arietinum L.} Yield

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Introduction & Purpose: Chickpea (Cicer arietinum L.) is a widely cultivated field crop in Anatolia. Traditionally, chickpea cultivation involves conventional fertilization methods. This study evaluated the effects of vermicompost application advantages on soils where conventional chickpea cultivation is practiced. Vermicomposts are more qualified in terms of chemical and biological content compared to other organic materials. They are rich in microbial content and contain high amounts of agriculturally beneficial microorganism groups. Chickpeas are plants successfully infected by heterotrophic Rhizobium ciceri strains that nodulate. The effects of three different fertilization methods on soil chemical and biological properties and chickpea yield parameters were investigated, including traditional chemical fertilization, manure application, and vermicompost application on chickpeas in two different groups: rhizobium-inoculated and non-inoculated.

Material and Method: Traditionally, 18-46-0 chemical fertilizer was applied at 15kg.da-1. Two different doses, 5% and 10%, were applied for vermicompost and manure. The experimental design included six different fertilization applications, two different chickpea seeds (rhizobium-infected and non-infected), and three parallel pots, totaling 36 pots. The study was established and conducted under controlled conditions in a plant growth chamber. Since the experimental period was determined until the flowering stage, soil and plant sampling were performed on the 40th day.

Findings & Conclusion: Chemical and biological parameter analyses (pH, EC, organic matter, total N, available P, exchangeable Na, K, Ca, Mg, microbial biomass C, soil respiration, dehydrogenase activity) were conducted on soil samples taken from the pots. For plant samples, effective nodule count, effective nodule fresh weight, root weight, root total N content, above-ground part total N content, above-ground part fresh weight, and above-ground part dry weight values were determined. In light of the obtained data, the effects of vermicompost on soil and yield parameters in rhizobium-inoculated and non-inoculated groups were evaluated comparatively with the effects of the control group without any application, chemical fertilizer, and manure applications.

Keywords: Chickpea, rhizobium, soil biology, soil parameters, vermicompost

Effects of Military Training, Warfare and Civilian Ammunition Debris on the Soil Organisms

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Introduction & Purpose: Civilian and military activities are sources of water and soil contamination by inorganic and organic contaminants caused by shooting practices, warfare, and/or mechanized military training. Lead poisoning and contaminant bioaccumulation due to spent shots or other related military contaminants have been widely studied for mammals, birds, and plants. Although there are different papers on the impact on earthworms, information on micro and mesofauna (i.e., collembola, nematodes, etc.) is still scarce.

Material and Method: Here, we review the published data regarding the impact of civilian and military shooting activities, including war-impacted areas, focusing on soil organisms, from microbial communities to the ecotoxicological effects on terrestrial organisms.

Findings & Conclusion: One hundred eleven studies were considered where earthworms and enchytraeids were widely studied, especially under ecotoxicological assays with Pb and energetic-related compounds from military explosives. There is a lack of information on soil organism groups, such as mites, ants, or gastropods, which play important roles in soil function. Data from combined exposures (e.g., PTEs + TNT and PTEs + PAHs) is scarce since several studies focused on a single contaminant, usually Pb, when combined contaminants would be more realistic. Ecotoxicological assays should also cover other understudied ammunition elements, such as Bi, Cu, or W.

Keywords: Military training, shooting ranges, heavy metals, organic contaminants

The Importance of Enzyme Activities in Soil For Plant Nutrition

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Introduction & Purpose: Soil enzyme activities play a critical role in soil fertility and nutrient solubilization. Enzymes are biocatalysts secreted by microorganisms present in soil and play a central role in the processes of decomposition of organic matter, transformation of nutrients and plant access to these elements. Soil enzyme activities are considered an indicator of the biological functionality of the soil ecosystem.

Material and Method: Enzymes present in soil drive different biochemical processes. For example, phosphatases facilitate phosphorus uptake by plants by converting organic phosphorus compounds into inorganic phosphorus. The enzyme urease is involved in the conversion of organic nitrogen compounds into the form of ammonia and then nitrate, thus meeting the nitrogen needs of plants. Furthermore, enzymes such as cellulases and ligninases accelerate the decomposition of plant residues and organic matter, increasing the organic carbon content of the soil and improving soil structure. High soil enzyme activities indicate high soil biological activity and fertility. These activities support plant growth and productivity by increasing the bioavailability of nutrients in the soil. Enzyme activities are influenced by soil management practices and environmental conditions. For example, the addition of organic matter and appropriate agricultural techniques can increase soil enzyme activities, while chemical fertilizers and pesticides can negatively affect these activities.

Findings & Conclusion: Consequently, soil enzyme activities are key components of soil fertility and nutrient solubilization. Soil management strategies should be designed and implemented to support these enzyme activities. This is vital for sustainable agricultural practices and long-term soil health.

Keywords: Soil, enzyme, yield, plant nutrition, sustainable agriculture

Soil Microbes and the Carbon to Nitrogen Ratio Indicate Priming Effects Across Terrestrial Ecosystems

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Introduction & Purpose: The control of the exogenous carbon-induced soil-priming effect (PE) by soil microbes, carbon, nitrogen, and carbon/nitrogen is still uncertain. To examine the relationship between diverse soil properties and the PE, the research was conducted using soils from forest, cropland, and grassland ecosystems.

Material and Method: We introduced a solution of 13C-labeled glucose (containing 6 atom %13C) into soils collected from three distinct ecosystems. For the control group, we added an equal amount of water to the soils. Subsequently, all treatment and control samples were incubated at 60% of their water holding capacity and maintained at a temperature of 25°C for a period of 28 days.

Findings & Conclusion: The magnitude of priming on native SOC was significantly higher in grassland ecosystems than in forest and cropland ecosystems. The results of structural equation modelling revealed a significant positive association of the PE with the soil carbon/nitrogen ratio, bacterial diversity, and community composition, as well as a negative association of the PE with SOC, dissolved organic carbon, and total nitrogen. Network analysis showed that the keystone taxa for each ecosystem were different. Sphingomonas, SBR1031, BD2-11-terrestrial-group, and Sebacina were the keystone taxa significantly positively associated with the PE, whereas Solirubrobacter, Bacillus, and Preussia were the keystone taxa significantly negatively associated with the PE. Our findings are significant for studying carbon fluxes, improving soil carbon dynamics models, and understanding soil microbe, carbon, and nitrogen relationships with SOC mineralization. This understanding is crucial for mitigating climate change, promoting sustainable land management, and enhancing soil carbon stabilization.

Keywords: Soil organic carbon mineralisation, exogenous carbon input, microbial community composition, terrestrial ecosystems

Effects of Arbuscular Mycorrhizal Fungi and Plant Growth Promoting Rhizobacteria on Growth and Yield of Cucumber Under Water Deficit Stress

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Introduction&Purpose: In arid and semi-arid regions, including Türkiye, waters car city is the most important factor limiting agricultural production, especially given the threat of global warming. However, the use of drought-resistant plants in combination with beneficial soil micro organisms can reduce the effects of drought. The use of arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria to in crease plant resistance to abiotic stresses such as drought is becoming increasingly common.

MaterialandMethod: This study was conducted to investigate the effects of single and combined use of a {Funneli for mismos seae} strain (AMF) and a {Pseudomonasputida} strain (PGPR) on the growthand yield of cucumber ({Cucumissativus} L.) under three different irrigation regimes (50%, 75% and 100% of the soil water holding capacity (SWHC)) in grenhouse conditions. The parameters measured included plant height, plant wet and dry weight, root wet and dry weight, stem diameter, number of leaves, leaf nutrient content, number of fruits per plant, average fruit weight and yield.

Findings&Conclusion: Single and combined use of AMF and PGPR increased plant growth parameters and yield compared to the control treatment under all irrigation regimes. Decreases in all parameters were observed as water constraint increased. However, this effect was statistically significantly lower in AMF and PGPR treatments. Maximum values were obtained with AMF+PGPR treatment under 100% SWHC. Under 75% SWHC, AMF+PGPR treatment increased plant height, stem diameter and yield by 29%, 30% and 50%, respectively, compared to the control treatment. The results indicate that treatments containing a combination of these particular PGPR and AMF stains may have a high potential for use in crop production in drought-stressed areas.

Keywords: AMF, biofertilizer, drought, PGPR, water stress

Effect of Wood Vinegars from Different Organic Wastes on Maize Yield, Plant Nutrients, and Seed Germination

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Introduction&Purpose: Organic wastes hold significant agricultural potential as they can be used as soil conditioners, making them valuable inputs for agriculture. Wood vinegar, a by product of biochar production can serve as an effective soil conditioner, improving soil characteristics and promoting plant growth. With its rich composition of organic acids, aldehydes, ketones, phenols, and furan compounds, wood vinegar is recognized for its beneficial effects on plant cultivation.

Material and Method: This study investigated the effects of wood vinegars derived from various feed stocks—oakwood, pistachio pruning waste, and chicken manure—on maize yield parameters and the concentrations of macro- and micro nutrients in the plant, using a pot experiment. The wood vinegars were diluted with water at concentrations of 1%, 2%, 3%, 4%, and 8%, and applied to the potting soil. Shoot and root growth measurements were taken to evaluate the influence of wood vinegar, in combination with optimal chemical fertilization, on maize silage yield. Additionally, chemical analysis was performed to assess the impact of wood vinegar on essential plant nutrients. A germination experiment was also conducted to assess the effects of different wood vinegar doses on seed germination rates.

Findings&Conclusion: The highest shoot lengths were recorded at the dose of 2% wood vinegar. Furthermore, significant changes in the concentrations of specific macro- and micro nutrients were observed, varying with the type and dose of wood vinegar applied. In the germination test, higher doses of wood vinegar from oakwood and pistachio pruning waste exhibited toxic effects, starting at the 3% dose.

Keywords: Organic wastes, waste management, wood vinegar

Determination of Sorgoleone Synthesis Levels in Different Sorghum Varieties Cultivated in Türkiye and the Effect of Sorgoleone as a Biological Nitrogen Inhibitor on Soil

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Introduction & Purpose: Modern agricultural systems are highly inefficient in nitrogen utilization, with 50-70% of the applied reactive nitrogen being lost in production processes due to natural occurrences within soil systems. Moreover, widely used nitrogen fertilizers, particularly urea, have low nitrogen use efficiency and contribute to environmental pollution and health hazards. The low nitrogen use efficiency (NUE) reported in agricultural systems is largely a result of nitrogen loss associated with nitrification-denitrification processes (Sahrawat & Keeney, 1985; Raun & Johnson, 1999; Galloway et al., 2008; Schlesinger, 2009). In addition to synthetic nitrification inhibitors used in soils, some plants can inhibit nitrification in the soil through metabolites secreted by their roots. Sorghum roots secrete two types of biological nitrification inhibitors: hydrophilic and hydrophobic. The hydrophobic metabolite, sorgoleone, constitutes 70% of the biological nitrification activity. Sorgoleone inhibits the ammonium monooxygenase enzyme activity, thereby preventing nitrification in the soil and maintaining nitrogen in the ammonium form, which plants more readily absorb. Additionally, inhibiting nitrification prevents the leaching of nitrate, the mobile form of nitrogen, into groundwater. Studies in the literature have primarily focused on the effects of sorgoleone in acidic, light-textured, lime-free soils with high organic matter content. However, to our knowledge, there has been no study on the biological nitrification inhibitory effects of sorgoleone on Turkey's soils, which are characterized by high salinity, lime content, alkalinity, and low organic matter. This study will evaluate the effects of sorgoleone from sorghum varieties Aldarı, Akdarı, Beydarı, Öğretmenoğlu, Gözde 80, Erdurmuş, Uzun, and E. sumac cultivated in Turkey.

Material & Method: In the greenhouse experiment, soil samples were collected on the 10th, 30th, and 60th days from pots containing eight different sorghum genotypes and control pots. These samples were then analyzed for exchangeable ammonium and nitrate.

Findings & Conclusion: The pot experiment conducted in the greenhouse, involving the analysis of exchangeable ammonium (NH_4+) and nitrate (NO_3-) from soil samples taken from the rhizosphere regions of different sorghum varieties, demonstrated that sorghum variety has a significant effect on ammonium and nitrate accumulation. By the 60th day, the lowest ammonium accumulation was recorded in the "Uzun" variety (25.64 ppm), while the highest was observed in the "E. Sumac" variety (45.62 ppm). In terms of nitrate accumulation, the nitrate levels in the control group were higher than those in the sorghum varieties at all sampling times, reaching 1480.2 ppm by the 60th day. Among the plant groups, the lowest nitrate accumulation was in the "Uzun" variety (1054.09 ppm), while the highest was in the "Öğretmenoğlu" variety (1340.70 ppm). These findings highlight the potential effects of sorgoleone on the nitrogen cycle and the differences among sorghum varieties, aiming to investigate the sustainability of biological nitrification inhibitors as alternatives to synthetic inhibitors.

Keywords: Sorghum, Sorgoleone, biological nitrification inhibition (BNI) activity nitrogen use efficiency

Short-Term Impact of Bokashi Compost Application on Physical Properties of a Soil: Incubation Study

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Introduction & Purpose: Bokashi composting is one of the cheapest and easiest methods to efficiently reduce organic waste and transform it into reusable organic matter in the soil. Bokashi composting practices are of great importance for environmental sustainability.

Material and Method: This study, the effect of bokashi compost on some physical properties of soil was investigated. The study was carried out in two stages as compost making and incubation trial. In the first stage, bokashi compost was made from vegetable and fruit wastes and in the second stage as incubation trial. Bokashi compost was added in 1%, 2%, 4% and 8% doses on weight basis and soil samples were left for 45 days incubation at field capacity moisture level. In the study, aggregate stability, average weighted diameter, atterbeg limits, modulus of rupture, field capacity, permanent wilting point, available water content were determined from the physical properties of the soil.

Findings & Conclusion: As a result of the study, the increase in aggregate stability, mean weight diameter, liquid limit, plastic limit values of the soil of bokashi compost applied to the soil was found to be statistically significant and the highest increase was realized in the 8% dose application. The treatments increased aggregate stability by 21-36% and mean weight diameter by 118%. With this study, it was concluded that bokashi compost will provide improvement in soil physical properties in a short time as well as easy waste disposal.

Keywords: Bokashi, compost, organic waste, vegetable-fruit waste, soil physical properties

Determination of the Effects of Compost and Liming Obtained from Tea Wastes on Some Soil Properties

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Abstract: In the Eastern Black Sea Region, approximately 205,100 producers are engaged in tea cultivation in an area of 791,300 decares. The production in tea gardens decreased by an average of 20% in 2022, and by 30% in some regions and gardens. While no problems were observed in the tea soils grown in the vast majority of the Eastern Black Sea region until the last thirty years, today it faces many problems.

A project was launched in Rize in 2016 with the slogan "For Every Dem Soil" in cooperation with the TEMA Foundation and DoğuşÇay to draw attention to the acidification problem in tea soils. Since 2018, hoeing and agricultural lime application, tea waste compost and organic fertilizer applications (TEMA application) have been carried out in 9 different gardens in Rize province.

In this report, 3 tea gardens (Buzlupınar, Sabuncular and Gündoğdu) soil analysis results were given. As a result; there was an increase between 0.50 and 1.00 units in the pH of the soils where TEMA application was applied. Organic carbon, soil respiration and microbial biomass values showed a significant increase at the $P<0.05$ level in TEMA applications compared to conventional and control applications. Organic and low-input systems have a higher fungus/bacteria ratio than enriched conventional systems. In the trial gardens, the fungus/bacteria ratio showed a significant increase at the $P<0.05$ level in TEMA applications compared to other treatments. Acid phosphatase and betaglucosidase enzymes responsible for biogeochemical cycles increased in TEMA applications compared to control applications. Similarly, Catalase enzyme, which is effective in meeting the oxygen needs of microorganisms in the soil, was found to be high in TEMA applications. The results of this study showed that the use of organic fertilizers to reduce the dependency on chemical fertilizers in tea cultivation helps to improve soil health.

Key words: Tea plant, organic fertilizer, compost, soil

Nitrogen Use Efficiency Under Stress Conditions: Current Approaches and Trends

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Introduction & Purpose: Nitrogen is one of the most crucial macronutrients for enhancing productivity in plant production. However, nitrogen use efficiency (NUE) varies significantly depending on the plant species, genetic makeup, and environmental stress factors encountered. One of the primary methods to improve NUE in plants involves genetic approaches that optimize nitrogen uptake and utilization. Advances in genomics and biotechnology have enabled the identification of genes regulating nitrogen metabolism and their application in plant breeding processes. Functional analysis of genes involved in nitrogen transport, storage, and transformation is critical in enhancing NUE in plants.

Material and Method: Environmental stress factors have significant impacts on NUE in plants. Conditions such as water scarcity, salinity, high temperatures, and low temperatures can adversely affect nitrogen uptake and metabolism in plants. Managing nitrogen in the soil is also crucial for preventing environmental pollution. Enhancing agricultural productivity under stress conditions while maintaining soil health is essential for sustainable nitrogen management. Developing stress-resistant plant species and investigating adaptation mechanisms in existing species are vital for improving NUE. Appropriate nutritional strategies play a crucial role in increasing NUE in plant production. Key approaches to consider include proper fertilization techniques and timing, improving soil structure, and optimizing plant-microbial interactions. Applying nitrogen fertilizers at the correct amounts and times not only enhances economic efficiency but also reduces environmental pollution.

Findings & Conclusion: In conclusion, genetic, environmental, and agronomic approaches to improving NUE in plant production hold significant potential for sustainable agriculture and food security. This paper aims to evaluate current strategies and new approaches that minimize the effects of environmental stress factors and optimize nutritional solutions.

Keywords: Nitrogen use efficiency, stress, crop improvement, nanotechnology

Greenhouse Gas Emission From Soils in the Coastal Zone of the Russian Arctic

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Introduction & Purpose: The interaction of coastal ecosystems with the atmosphere under conditions of global climate change is especially important for the overall development of the biosphere. The aim of our study was to assess the spatial variability of the carbon efflux from the soils of coastal ecosystems of the White and Barents Seas.

Material and Method: We conducted our research on the Pomor coast of the White Sea near the village of Kolezhma (64°13' N 35°56' E) and in the southern part of the Chosha Bay, the Barents Sea, near the village of Belushie (66º89' N 47º57' E). Measurement of carbon dioxide emissions from the soil surface was carried out using a portable gas analyzer from LICA United Technology Limited (model PS-9000). As a result of the conducted study, the spatial distribution of carbon emissions in the soils of coastal ecosystems of the White and Barents Seas was determined for the first time.

Findings & Conclusion: Analysis of carbon emissions from soils of the White sea and Barents Seas coastal ecosystems indicates their high spatial variability. Underestimation of spatial heterogeneity of soil properties can lead to significant distortions of estimates of total greenhouse gas emission and models of climate change in this region. The results obtained on the basis of statistical analysis of a large array of data will serve to better understand the role of coastal ecosystems in global greenhouse gas emissions. The results not only make a fundamental scientific contribution to the field of studying the ecology of specific and unique ecosystems of the Arctic seacoasts, but also allow us to identify and clarify the factors and mechanisms that determine greenhouse gas emission from this region. This research was funded by the Russian Science Foundation, grant numbers 23-67-10006 "Blue carbon" stock and dynamics of the sea coasts of the western sector of the Russian Arctic.

Keywords: Climate change, carbon cycle, blue carbon, marsh

POSTER

The use of Computed Tomography to Study the Effect of Fertilization on Soil Porosity During a Long-term Experiment

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Introduction&Purpose: The aim of this contribution is to present the results of soil porosity obtained in the Czech Republic as part of the SoilX project. In order to fulfil the objectives of the Project from the Czech side, field measurement sand sampling were carried out in spring 2023 at two locations, Čáslav (Luvisol) and Lukavec (Cambisol).

Material and Method: Two contrasting variants were studied at both sites: control and fertilised with manure and N2PK. Plastic column swith a diameter of 7 cm and a height of 12 cm were collected at a depth of 1-13 cm (Aphorizons) and 30-42 cm (Bwand Bt horizons in Lukavec and Čáslav, respectively). These samples were used for porosity measurements using computed tomography (CT) NIKON XTH 225 ST. In addition, set of three 100 cm3 und is turbed soils samples were taken from each horizon to measure porosity and soil hydraulic properties using standard methods.

Findings&Conclusion: The results from the Lukavec site show that the porosity determined from the plastic column samples obtained by CT is higher in the Ap horizon in the control than that in the fertilized variant, whileno effect of fertilization is observed in the Bw horizon. Where as at the Čáslav site, the effect of fertilisation is evident. The fertilised variant showed higher porosity in the Ap horizon and lower porosity in the Bt horizon compared to the control. The results obtained on the 100 cm3 correspond to the CT observations. This project has received funding from the European Union´s Horizon 2020 (No 862695).

Keywords: CT, image analysis, long-term experiments, porosity, SoilX

Influence of Compost Application on Soil Surface without Incoporation on Selected Physical Properties of Soil

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Introduction & Purpose: The application of stable compost on the soil surface without incorporation positively affects soil physical properties, but few studies have addressed this. This study evaluated the effect of surface-applied non-incorporated stable compost on soil aggregate stability and unsaturated soil hydraulic conductivity.

Material and Method: Conducted in-situ at two Czech agricultural sites (A: Blatnice at Jaroměřice, B: Jevíčko) as a semi-operational field experiment, plots were treated with surface compost and control plots without compost. Compost application rates were 20 and 200 t/ha and the sites were cultivated with wheat and maize, respectively. In-situ infiltration tests were conducted during the 2023 vegetation season using mini-disc infiltrometers. Disturbed soil samples were collected to determine soil aggregate stability via the wet sieving method.

Findings & Conclusion: Results demonstrated a significant effect of surface compost application on soil properties. At site A, average aggregate stability was 0.75 WSA for compost-treated soil, significantly higher ($p < 0.001$) than 0.66 WSA for the control. At site B, three sampling rounds during the season showed average aggregate stability of 0.62 WSA for compost-treated soil versus 0.49 WSA for control ($p < 0.0001$). Unsaturated hydraulic conductivity at site B, measured at a pressure head of -2 cm, was significantly higher for compost-treated soil (3.58 x 10^-3 cm/min) compared to control (1.05 x 10^-3 cm/min). At site A, the difference was statistically insignificant.

Keywords: Stable compost, soil aggregate stability, unsaturated hydraulic conductivity, minidisk infiltrometer

Acknowledgment: Ministry of Agriculture of the Czech Republic, National Agency for Agricultural Research, project No. QK22020032.

Reliable Indirect Determination of Field Capacity: Simple and Budget-Friendly Method

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Introduction & Purpose: Field capacity (FC) is defined as the maximum amount of water soil can hold against the force of gravity after excess water has drained away. This study presents a cheap, fast and uncomplicated technique for indirectly determining FC in soil, which is a crucial parameter for environmental modeling and irrigation applications. The objective was to lower the time and expenses linked to conventional FC measurement techniques, and to enable the utilization of legacy databases comprising maximum capillary water capacity (MCWC) and retention water capacity (RWC) figures.

Material and Method: Relationships between FC (determined as water content at certain set matric potentials) and soil moisture constants, specifically MCWC and RWC, were established using undisturbed soil core samples analyzed by pressure plate method and by “filter paper draining method”. This method involves determining the gravimetric soil water content of core samples. The samples were saturated and then allowed to drain naturally on the filter paper for a specified time interval (max. 24 hours). This method has long history of use in the Czech Republic as an approximate of FC, but it has never been correlated with a soil water content determined at a specific matric potential.

Findings & Conclusion: The outcomes exposed the significant possibility of the “filter paper draining method” as an encouraging strategy for indirect FC determination, tested on more than 700 samples. FC as soil water content at -33 kPa can be well approximated by the equation FC33 = 1.0802 RWC - 0.0688 (with RMSE = 0.045 cm3/cm3 and R = 0.953). For FC as soil water content at -5 or -10 kPa, either of the following equations can be used: FC5 = 1.0146 MCWC - 0.0163 (with RMSE = 0.027 cm3/cm3 and R = 0.961) or FC10 = 1.0152 MCWC - 0.0275 (with RMSE = 0.033 cm3/cm3 and R = 0.958), respectively.

Keywords: Field capacity, filter paper draining method, maximum capillary water capacity, pedotransfer functions, retention water capacity

Assessment of Long-Term Urbanization Impact of Heavy Metal Pollution in Wetland Soils in Krakow, Poland

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Introduction & Purpose: Wetlands, in light of current climate change, are a very valuable element of the environment, especially in urban areas. They have an important function in preserving biodiversity, water retention and also have recreational value. In the past, the area of Krakow city was abundant in wetlands however due to the increasing urbanization and industrialization and draining of wetlands impacted in maintenance of only a few small enclaves to this day. The soils of these areas, often organic soils, are exposed to the accumulation of various pollutants, especially heavy metals. This study was done to determine the total content of heavy metals in soil, assess the pollution degree using individual as well as complex pollution indices and identify the potential pollution sources.

Material and Method: Field studies were conducted in 6 study plots in Krakow and samples was taken from a depth of 0-30 cm soil layer.

Findings & Conclusion: Due to the high organic matter content, most of the studied soils were classified as Histosols according to WRB. The content of heavy metals in studied soils was in the order: Zn > Pb > Cr > Cu > Ni > Cd. The values of pollution indices were strongly influenced by the type of geochemical backgrounds used. The results showed that anthropogenic influence particularly affected the elevated content of Cd, Pb and Zn in the studied soils.

Keywords: Organic soils, urban areas, pollution indices

Alteration of Soil Properties Under Two Long-term Experiments in the Czech Republic

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Introduction & Purpose: The aim of this contribution is to present the results of soil properties obtained in the Czech Republic as part of the research project SoilX. The SoilX Project as a part of EJP SOIL addresses 3 main research questions: 1. How exactly did soil management alter soil hydraulic properties in long-term field experiments across Europe? 2. To what extent can soil structural improvements enhance the resilience of cropping systems to future precipitation extremes? 3. Which socio-economic factors enable soil management improvements? Contrasting soil management treatments in 12 long-term agricultural field experiments (LTE).

Material and Method: To fulfil the objectives of the project from the Czech side the field measurements and sampling were carried out in the spring of 2023 at two locations, Čáslav (Luvisol) and Lukavec (Cambisol). Two contrasting variants were investigated at both sites: control (no fertilizers and other enrichments) (MIN), and manure and N2PK fertilized soil (FYM). In the field, a penetration resistance, soil CO2 efflux, field soil water content (SWC), earthworms' abundance, and unsaturated hydraulic conductivity were measured. Grab soil samples were taken to evaluate basic soil properties (soil pH, soil organic carbon content (SOC), texture) and stability of aggregates (WSA index). Undisturbed samples were taken to measure the hydraulic and total porosity (P).

Findings & Conclusion: Data obtained within this project and data gained before during LTE will be used as inputs into selected biophysical models to estimate the benefits of soil structural improvements for mitigating the impacts of increasing precipitation.
Acknowledgment: This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 862695. Realized with the financial support of the Ministry of Education, Youth and Sports.

Keywords: Fertilisation, long-term experiments, soil management, soil structure, SoilX

The Soil Nitrogen Status of Four Small Grain Production Areas in Turkey

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Introduction & Purpose: In Turkiye, wheat production is a significant area of research, given the importance of bread in the country's diet. The fallow system is utilized in arid and semi-arid climate regions to ensure sufficient soil moisture and nitrogen accumulation. Strategic use of nitrogen fertilizers is crucial for optimizing fallow agricultural systems in specific areas of Turkiye. This research was conducted approximately 65 years ago and holds both scientific and historical significance. The study's reference could not be found in the Plant Nutrition Department of the Agricultural Faculty in Ankara, nor could it be found in the Department of Nebraska Agronomy, USA, where the first author of the study is located and completed it. The main purpose of the research, which has unique historical and scientific significance, is to ensure access to everyone interested in the subject.

Material and Method: In the study, the research report of Fox et al. Burhan Kacar, Akgün Aydeniz, Sevim Zabunoğlu, Mecit Çağatay Evaluation of "The Soil Nitrogen Status of Four Small Grain Production Areas in Turkey" 1956-1958. which is in the author's private file, was used. Wheat-nitrogen experiments were conducted in 11 production and research by the Ministry of Agriculture mostly in the Central Anatolia Region, Turkiye, and 4 fields of villagers also as well. Analytical works and certain greenhouse studies were conducted in the Ankara Plant Nutrition Department of Agriculture Faculty.

Findings & Conclusion: Nitrogen fertilizer increased the yield of winter wheat if moisture or phosphorus were not limiting factors. Under fallow conditions, the best indicator of the need for nitrogen fertilization seems to be the total nitrogen content of the soil. No response from nitrogen fertilizer is expected when total soil N exceeds 0.114%. It is suggested that planting systems that permit earlier wheat germination will promote the development of a vigorous root capable of extracting soil and subsoil moisture more.

Keywords: Soil, nitrogen, grain, Türkiye

Investigation of the Effects of Different Doses of Vermicompost Applications on Some Physical, Chemical and Biological Properties of Soil

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Introduction & Purpose: Vermicompost use is one of the most effective ways to increase soil organic matter and soil microbial vitality, which are important parameters for sustainable agricultural practices. The aim of this study is to determine the effects of vermicompost applications alone and with chemical fertilizers on some important physical (bulk density, aggregate stability, aeration capacity and available water), chemical (pH, EC, total N, available phosphorus and extractable potassium) and biological (CO2, MBC, qCO2, qmic) parameters of barley grown soil.

Material and Method: In the field experiment, decreasing doses of chemical fertilizer (100%, 75%, 50% and 0) and increasing doses of vermicompost (0, 25%, 50% and 100%) were applied based on the calculation of total nitrogen (N) amount required in barley cultivation.

Findings & Conclusion: According to the results obtained from the field experiment; In all applications with vermicompost, aggregate stability, aeration capacity and available water amounts increased, while bulk density decreased compared to control and chemical fertilizer application alone ($P<0.05$). On the other hand, vermicompost applications increased total nitrogen and extractable potassium amounts from the chemical properties of the soil at $P<0.05$ significance level. It was determined that vermicompost applications also had positive effects on soil respiration and microbial biomass carbon, which are indicators of the activity of soil microorganisms from soil biological properties. When the microbial coefficient (qmic) of the experimental soils was evaluated; while the changes due to the applications were not statistically significant, the metabolic coefficient (qCO2) gave the highest value in chemical fertilizer application. A high qCO2 value is one of the indicators that organic substrates are less productive in terms of microbial biomass.

Keywords: Vermicompost, organic carbon, biological index, sustainable agriculture, agregate stability

Prediction of Rill Erodibility and Critical Shear Stress Variables in the WEPP Model by Fluidized Bed Approach

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Introduction & Purpose: Rill erosion is one of the most important environmental problems in agricultural areas. In this study, rill erodibility (Kr, s m-1) and critical flow shear stress (τcr) variables of WEPP model (Water Erosion Prediction Project) that evaluates rill erosion process-based were associated with cohesion measurements obtained by the fluidized bed approach, which emerged as a new approach, to investigate this approach's ability to measure these variables more easily and parametrically.

Material and Method: In this context, rill erosion measurements were performed and compared with WEPP model base-line equations and cohesion values for several soil types.

Findings & Conclusion: Within the scope of the obtained findings, the observed relationships between cohesion developments and rill erodibilities of soils having different structural properties were evaluated with various statistical approaches. The relationships between the Kr values obtained by measurement under laboratory conditions and the mechanical cohesion properties were found to be statistically significant ($p < 0.01$). In addition, statistically significant relationships were obtained between the Kr values and other soil properties (SDA, porosity, particle size distribution etc.) ($p < 0.01$). The findings showed that it is possible to predict the rill erodibilities of soils with cohesion measurements by fluidized bed approach and that the rill erosion has the potential to be successfully simulated in an easy, simple and practical way with the help of the cohesion measurements by the approach.

Keywords: Critical shear stress, fluidized bed approach, rill erodibility, soil cohesion, WEPP model

Impact Assessment of Microplastics in Agricultural Soils of the Euroregion Galicia and Minho: Preliminary Results

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Introduction & Purpose: Plastic has become an essential component of modern agriculture. However, studies have shown that plastic waste can adversely affect soil health and biodiversity, soil productivity and food security. As the demand for agricultural land continues to increase and resources become scarce, it is pivotal to prevent further degradation of agricultural soils. Few studies were conducted in the NW of the Iberian Peninsula on the potential distribution of microplastics (MPs) in agricultural soils. Therefore, it is urgent to understand how plastics can impact different agricultural soils in the Euroregion of Galicia and Minho-North of Portugal.

Material and Method: The broad objective of the study is to develop a harmonized methodology for evaluating the impact on soil health caused by the extensive use of plastic materials. Microplastics contents will be determined in different types of agricultural land using novel techniques for extracting plastics from complex mixtures, such as agricultural soils. Also, the study will investigate the potential sources of plastic in the soil system and the role of microplastics as carriers of other contaminants. For both regions, different types of agriculture were identified in the study areas: urban vegetable gardens and urban farming, farm greenhouses, and intensive grapevine, corn and wheat production.

Findings & Conclusion: In spring/summer 2024, soil samples were collected from 0-20 cm of the soil profile following the LUCAS guidelines and kept in aluminium takeaway containers for transportation. In the laboratory, samples were dried at room temperature for one week, followed by 48 hours at 40 °C. The soil was dry sieved to obtain the < 2 mm particle size fraction. The current project stage comprises the determination of the soil physicochemical properties. A harmonized methodology for the routine analysis of (micro) plastics in soils is currently under development with a density extraction method with K_2CO_3.

Keywords: plasticulture, plastic contamination, agricultural productivity, organic contaminants, Iberian peninsula

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