ISSN: 2993-5377

Research Article

Open Access Journal of Applied Science and Technology

Exploring the Physical, Chemical, and Biological Properties of Soils from Different Regions Classified into Different Textural Classes

Mohammed Saba[1*], Ummahan Çetin Karaca[2] and Samir G. Al-Solaimani[1]

[1]*Department of Agriculture, Faculty of Environmental Sciences, King AbdulAziz University, Saudi Arabia*

[2]*Faculty of Agriculture Department of Soil Science and Plant Nutrition Selcuk University, Turkey*

[*]Corresponding Author
Mohammed Saba, Department of Agriculture, Faculty of Environment, King AbdulAziz University, Saudi Arabia.

Submitted: 2023, Dec 18 **Accepted:** 2024, Jan 11 **Published:** 2024, Jan 22

Citation: Saba, M., Karaca, U. C., AI-Solaimani, S. G. (2024). Exploring the Physical, Chemical, and Biological Properties of Soils from Different Regions Classified into Different Textural Classes. *O A J Applied Sci Technol, 2*(1), 01-07.

Abstract
Soil is a living, dynamic structure that plays critical roles in terrestrial ecosystems. Soil texture is an important soil property because it influences other important soil qualities such as soil structure, soil moisture, the diversity of living organisms, plant growth, and overall soil quality. Soil texture has an impact on the chemical and physical qualities of the soil, as well as enzyme activity and microbial population. The study's goal was to investigate the chemical characteristics, soil enzymes, and soil respiration of soils with various textures (sandy loam, clay loam, clay, sandy clay loam). Soil samples were collected from eight distinct regions (Kücükkoy, Fethiye, Dinlendik, İçer Çumra, Kuzucu, İnli, Alibeyhüyüğü, and Güvercinlik) at depths ranging from 0 to 30 cm in Konya's Cumra district, and four different texture classes were determined. The varying soil textural classes were found to have different impacts on pH, EC, lime, organic matter, macro and micro components, soil respiration, and various enzyme activities. These textural variations resulted in statistically significant differences. Variations in these factors were also shown to change the activities of specific soil enzymes. The results also show that clay-textured soil contains the highest amounts of micronutrients, soil respiration, catalase enzyme, as well as acidic and alkaline phosphatase enzyme activity.

Keywords: Basal Soil Respiration, Chemical Properties, Soil Texture, Enzyme Activities

1. Introduction

Soil texture affect soil physical and chemical properties, soil nutrients enzyme activity and microbial population [1-4]. Since soil quality depends on the physical, chemical, and biological properties of the soil, it is imperative to take all these properties into account when evaluating soil quality [5,6]. Evaluation of soil biological and biochemical properties is done from three different aspects. The first is biodiversity, in which the type, amount and distribution of microorganisms are determined, the second is population studies, in which the dynamics of special organisms and species used as biological indicators are determined, and finally, the biological cycle of soil enzymes, hence microbial activity, and the elements related to the transformation of organic matter are revealed in ecosystem studies. The objective of this study was to investigate the physical, chemical, and biological characteristics of soils obtained from various places and categorized based on their respective textural classes. Researchers can enhance their ability to manage and enhance soil health, hence impacting human nutrition, food security, and environmental health, by comprehending the characteristics of diverse soil types. Soil respiration serves as a significant indicator of various ecological processes within the ecosystem, including metabolic activities, plant residue decomposition, and the conversion of soil organic carbon into atmospheric CO2 [7,8]. The activities of soil enzymes exhibit a correlation with significant soil parameters, including organic matter content, texture, and pH. Soil respiration and soil enzyme activity serve as reliable indicators for assessing microbial activity in soil, as well as for evaluating alterations in soil quality resulting from land use practices [9]. The enzyme activity of dehydrogenase (DHG) in soil has been widely acknowledged as a reliable indicator of aerobic and facultative anaerobic microorganisms capable of releasing hydrogen through respiration from organic substances [10]. Several prior investigations have indicated that the activity of the dehydrogenase enzyme can serve as a dependable indicator of microbial activity in soil [11,12]. According to Brady and Weil clay soil exhibits a notable capability for adsorbing a wide range of salt ionic compounds [13]. This can be attributed to the substantial specific surface area and chemical association capacity of clay particles, as highlighted by Ge et al. (2019). In their study, Frankberger et al. (1983) observed that the introduction of residues and wastes containing high levels of organic matter resulted in an initial boost in soil microbial activity. Additionally, they noted that this increase in microbial activity led to a subsequent rise in urease activity. However, after a certain period, except within the soil root zone, urease enzyme activity decreased significantly. According to Aşkın et al. (2004), soil microbes boost soil enzymes activities to facilitate the decomposition of nutrients. These enzymes are well sequestered by soil colloids, including clay and organic matter. Consequently, the enzymes remain active and functional, independent of their association with microorganisms. The activity of catalase may be associated with the metabolic processes of aerobic organisms and has been used as an indicator of soil fertility [14]. The activity of microorganisms in soil is influenced by soil texture through its impact on soil temperature and water content [15]. On their study titled "Soil textural class plays a major role in evaluating the effects of land use on soil quality indicators" reported that studies of microbial and biochemical indicators and soil texture lead to a better under-standing of the ecological processes and soil function. Therefore, the current study explored the physical, chemical, and biological properties of central Anatolian soils for better agronomical decisions with regards to soil textural effect on crop yield in the regions [16]. The findings of this study have the potential to offer reliable insights into the development of more efficient farming practices in central Anatolia.

2. Material and Method

Soil samples were systematically collected from eight distinct neighborhoods within the Çumra district of Konya province, specifically at a depth of 0-30 cm. The locations from which soil samples were collected are Küçükköy, Fethiye, Dinlendik, Central Çumra, Kuzucu, İnli, Alibeyhüyüğü, and Güvercinlik. The samples were dried at room temperature to facilitate subsequent physical and chemical analysis. The samples were then passed through a sieve with a mesh size of 2 mm. A total of eight soil samples were analyzed, from which four distinct texture classifications were obtained [17]. In preparation for biological studies, soil samples were stored in a refrigerator at +4 oC and to ensure the preservation of the properties, were firmly sealed in containers until the time of analysis. The soil samples underwent a series of physical and chemical analyses, including textural determination, soil acidity (pH), electrical conductivity, calcium carbonate content analysis, organic matter analysis, macro and micronutrient analysis. The biological soil analysis done are: basal soil respiration, and dehydrogenase activity [18-20]. Additionally, catalase activity the acid phosphatase activity, the alkaline phosphatase activity, and the aryl sulfatase activity were measured [21].

3. Results and Discussion

The pH of the textural classes ranged from 8.1 to 8.5, indicating an alkaline of central Anatolia. The pH of the soils, in terms of texture, followed the order of SL > CL > C = SCL. Also found comparable results in their study [22]. They observed that soil texture had distinct impact on soil pH. Specifically, they observed a strong negative correlation between clay content and soil pH, whereas silt and sand particle contents showed a significant positive correlation with soil pH. A particle with a substantial surface area and sufficient pore space demonstrates higher conductivity, thereby affecting its potential for crop output [23]. Regarding salinity, the soil samples have electrical conductivity values ranging from 119 to 547 µmhoscm-1, with the order being SCL>C=CL>SL. This place the soil samples in the category of saline and mildly saline range. The carbonates concentration of the soil samples varied between 11% and 30%. Nevertheless, the distribution of carbonates concentration throughout the textural classes was not consistent. The carbonates content was ranked in the following sequence from highest to lowest: C > SL > SCL > CL. The organic matter content of the different soil texture groups varied between 0.9% and 2.4%. Significant statistical findings were reported regarding the impact of different soil textures on pH, electrical conductivity (EC), lime concentration, and organic matter. The soil's nitrogen concentration ranged from 223 to 441 mg/kg, with the soil of sandy clay loam texture exhibiting the highest nitrogen content. The soil sample characterized by a clay loam texture displayed the most minimal nitrogen concentration. The phosphorus concentration in soils with different textures ranges from 6 to 12 mgkg^{-1}, indicating low to medium levels.

Properties		**Textural classes**				**Methods**
		Sandy loam	**Clay loam**	**Clay**	**Sandy clay loam**	
pH		8.5 a	8.3 b	8.1 c	8.1 c	Richards 1954
EC (µmhos cm^{-1})		119 c	161 b	195 b	547 a	U.S. Salinity Lab. Staff 1954
$CaCO_3$ (%)		24 b	11 d	30 a	19 c	Hızalan and Ünal 1966
Organic Matter (%)		1.0 b	1.0 b	2.4 a	0.9 b	Smith and Weldon 1941
N (NH_4+NO_3)	mgkg^{-1}	233 c	223 c	362 b	441 a	Bremner 1965
P		6.0 c	6.0 c	12.0 a	8.0 b	Olsen et al. 1954
K		140 b	179 a	107 c	73 d	Soltanpour and Workman 1981
Ca		4075 c	4937 b	6976 a	4086 c	Soltanpour and Workman 1981

Mg		323 d	762 a	668 b	434 c	Soltanpour and Workman 1981
Fe		4.2 d	6.5 b	7.9 a	5.3 c	Lindsay and Norvell 1978
Cu		0.3 b	0.6 a	0.6 a	0.3 b	Lindsay and Norvell 1978
Mn		5.9 b	6.3 b	16.6 a	4.8 b	Lindsay and Norvell 1978
Zn		0.4 b	0.3 b	0.9 a	0.5 b	Lindsay and Norvell 1978
B		1.8 c	2.6 b	2.9 a	1.6 d	Richards 1954

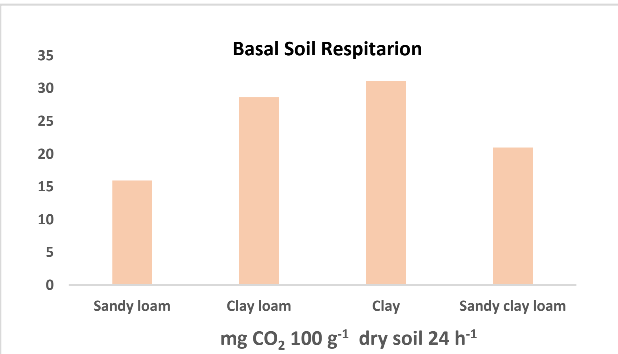
Table 1: Effects of soils with different on textures pH, salinity, lime and organic matter, macro and micro elements

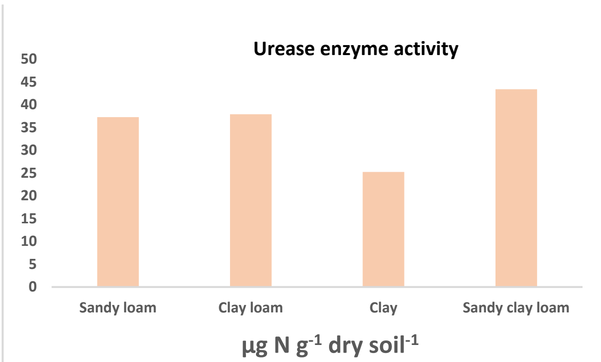
The soil with a sandy clay loam texture had the lowest potassium concentration, at 73 mgkg-1. The soil possessing a clay texture displayed the highest calcium concentration, measuring 6976 mgkg-1. The magnesium contents in soils with different textures varied between 323 and 762 mgkg-1. The statistical significance of the influence of soil texture on macro elements was assessed and presented in table 1. The iron concentration in soils with different textures varies between 4.2 and 7.9 mgkg-1, which is considered sufficient. The soil sample characterized by a clayey texture displayed the greatest concentration of iron. The soil samples displayed a varying copper content (0.3 to 0.6 mgkg-1). The soil sample characterized by a clay texture demonstrated the highest concentration of manganese, measuring 16.6 mgkg-1. In contrast, the soil sample with a sandy clay loam texture exhibited the lowest manganese concentration, measuring 4.8 mgkg-1. The zinc concentration of the soils varied from 0.3 to 0.9 mgkg-1. The boron contents vary between 1.6 and 2.9 mgkg-1. When examined, the soil sample with a clay texture frequently displayed the highest quantities of microelements. The statistical significance of the relationship between soil texture and microelement levels was observed.

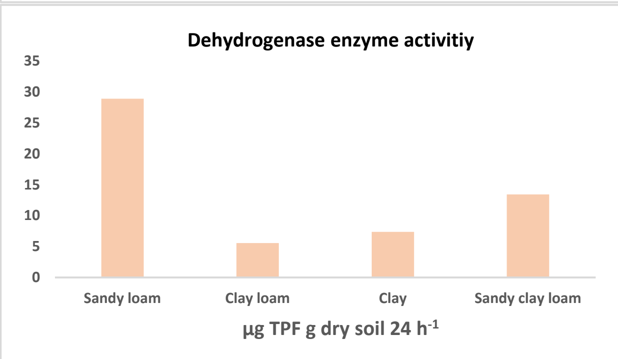
The basal soil respiration rates followed the order of C > CL > SCL > SL, demonstrating that soil respiration was higher in soils with finer textures. The correlation between the number of micropores in the soil and the level of basal soil respiration is evident in arid regions such as central Anatolia, where a greater abundance of micropores leads to increased basal soil respiration. The analysis found a significant difference in carbon dioxide emissions among soils with different textures, indicating a noteworthy mismatch. The carbon dioxide levels were influenced by the soil texture, with the clay-textured soil showing the highest value of 31.16 mg CO_2 100 g−1 dry soil 24 h−1, while the sandy loam soil had the lowest value of 15.97 mg CO_2 100 g−1 dry soil 24 h−1. Both values fall within the specified range of 14.29-28.57 units according to the report conducted a study which concluded that clayey soil has a greater degree of biological activity in comparison to other soil types [24,25]. The findings indicate that there is a positive correlation between the clay content of the soil and soil respiration. The order of soil respiration, from highest to lowest, can be derived as C > CL > SCL > SL based on the figure illustrating the link between soil respiration and textural classes. Dick (1994) states that urease is an enzyme that catalyzes the hydrolysis of urea, leading to the formation of carbon dioxide and ammonia. This enzyme has been recognized as the exclusive catalyst that has a substantial impact on the state and effectiveness of urea, an essential fertilizer, within the soil. The study examined variations in urease enzyme activity among soils with different textures and found that these differences were statistically significant ($p<0.01$). The soil with a sandy clay loam texture had the highest urease enzyme activity, measuring 43.39 µg N g-1 dry soil. It was followed by the clay loam and sandy loam soils. The soil with a clay texture had the lowest urease enzyme activity, measuring 25.24 µg N g-1 dry soil. Tabatai (1977) found that urease activity in soils is influenced by various parameters such as organic matter content, soil depth, soil amendments, heavy metals, and climatic conditions including temperature. While the urease enzyme activities obtained fall within the reported ranges by Hofmann et al (1966), it is important to note that Anatolia soils are predominantly clayey, and farmers commonly use urea as a nitrogen source. Therefore, implementing soil amendments that enhance urease activities in the Anatolia regions would likely result in increased soil productivity. The organic content of central Anatolia is deficient, which may result in reduced urease activity. Regarding the impact of temperature on urease activity, it is advisable to carry out urea fertilization of farms during hot weather conditions in order to enhance the enzyme's activity in the area. The impact of environmental factors, such as soil moisture, temperature, and organic matter content, on the activity of dehydrogenase enzyme has been well investigated [26]. The activity of dehydrogenase enzymes in soils with different textures were found to be different, and this difference was proven to be statistically significant. The investigation found that the activity levels of the dehydrogenase enzyme in the soils varied between 5.57 and 28.90 µg TPF g dry soil 24 h-1, as shown in Figure 3. The soil with sandy loam texture displayed the maximum dehydrogenase enzyme activity, whereas the soil with clay loam texture showed the lowest dehydrogenase activity. Enzyme activity of dehydrogenase below 50 µg TPF per gram of soil per 24 hours is considered to be poor, according to Tosun [27]. Most soils in central Anatolia have a clay loam texture, which, as indicated by recent research, demonstrates reduced dehydrogenase activity. Makoi and Ndakidemi highlight the need of investigating the activities of the dehydrogenase enzyme in soil [28]. This study offers significant findings regarding the soil's ability to sustain essential biochemical activities that are critical for maintaining soil fertility. The catalase enzyme facilitates the breakdown of hydrogen peroxide (H_2O_2) into water and oxygen. It is generated as a result of the respiratory and metabolic processes taking place within living organisms. The catalase enzyme activity levels of soils with different textures range from 1.73 to 5.60 ml O_2 per 5 g of soil. This variation has been found to be statistically significant. The soil sample with clay texture demonstrated the highest catalase enzyme activity, while the soil with sandy clay loam texture indicated the lowest catalase enzyme activity. The prolonged enzyme activity can be ascribed to the advantageous protective effect arising from the substantial adsorption capacity of clay and silt particles for enzymes. When the soil shows a signal of phosphorus deficit, plant roots increase the secretion of acid phosphatase to enhance the solubilization and remobilization of phosphate. This, in turn, affects the plant's capacity to survive conditions of phosphorus stress [29]. The acid phosphatase enzyme activity values were significantly influenced by the soil texture, as indicated by the observed statistically significant changes. The acid phosphatase enzyme displayed a wide range of values, ranging from 75.15 to 170.78 µg p-nitrophenol g-1 dry soil h-1. The soil with a clay texture exhibited the greatest reported level of acid phosphatase enzyme activity. The soil sample with sandy loam texture showed the lowest acid phosphatase enzyme activity value. The alkaline phosphatase enzyme activity values of the soils showed considerable statistical differences dependent on the soil texture. The detected alkaline phosphatase enzyme activity values ranged from 167.11 to 528.89 µg p-nitrophenol g-1 dry soil h-1, with the highest value found in soil with a clay texture. The alkaline phosphatase enzyme activity was found to be the lowest in the soil sample with a sandy clay loam texture. The activity levels of the arylsulfatase enzyme in soils with different textures showed variability among the soil types, although these variations were found to be statistically insignificant. The arylsulfatase enzyme's activity ranged from 273.56 to 281.49 µg p-nitrophenol g-1 dry soil h-1. The arylsulfatase enzyme activity value was highest in the soil with a sandy clay loam texture. The arylsulfatase enzyme activity value was found to be the lowest in the soil sample with a clay loam texture [30-46].

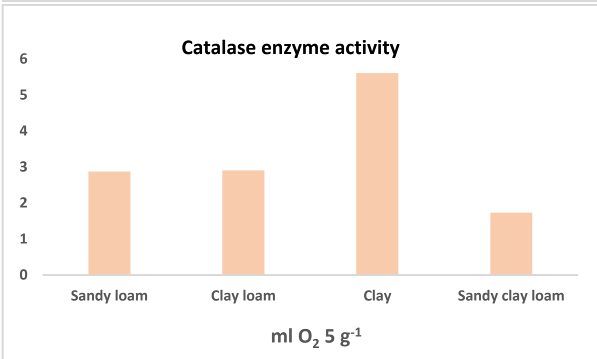
4. Conclusion

The soil is a system that includes its physical, chemical, and biological features. Each of these properties influences the soil's behavior at a different level and contributes to the overall determination of the soil's quality. In prior research, the quality of the soil is determined by looking at its several component aspects, including its physical and chemical composition. On their own, however, physical, and chemical qualities are not always sufficient to provide meaningful results when indicating the quality of soil. Evaluation methods that do not consider the biological features of the soil are insufficient. In recent years, biochemical soil characteristics have become an increasingly popular method for evaluating soil quality in a variety of contexts. Because of this, the impacts of soil texture on soil pH, EC, lime, organic matter, macro and micro elements, soil respiration, and some soil enzyme activities exhibited differences, and these differences were found to be statistically significant. In addition, the changes in these factors were shown to affect the activities of some soil enzymes. In general, values of microelements, soil respiration, catalase, acid, and alkaline phosphatase enzyme activities were found to be at their maximum levels in clay-textured soil. As a consequence of this, the texture of the soil is an essential component in determining the soil's physical and chemical characteristics, as well as its nutritional contents, enzyme activity, and microbial population.









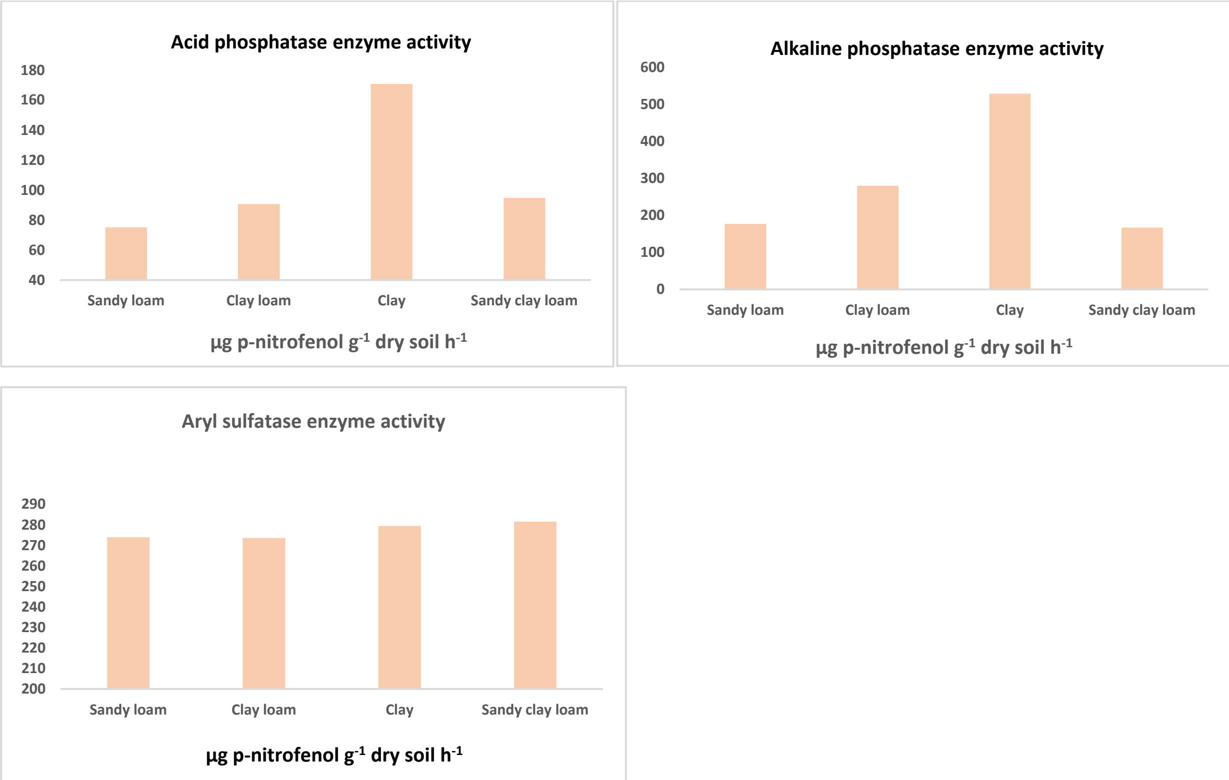


Figure 1: Effects of soils with different textures on soil respiration, urease, dehydrogenase, catalase, acid phosphatase, alkaline phosphatase, and aryl sulfatase enzyme activity

5. Declarations

• The authors hereby give approval and consent to participate in the "Ethics approval and consent to participate" section of the Declarations.

• All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

• Availability of data and material: the data used for the manuscript will be provided upon request.

• Competing interests: there are no any competing interests with regard to the study.

• Funding: No funding was obtained for this study.

• Authors' contributions: Mohammed Saba obatained the soil samples used for the study, wrote the chapter one and two as well the final editing of the final manuscript while Ummahan Çetin Karaca analysed the samples, wrote the chapter three and four.

References

1. Sheng, Y., Wang, H., Wang, M., Li, H., Xiang, L., Pan, F., ... & Mao, Z. (2020). Effects of soil texture on the growth of young apple trees and soil microbial community structure under replanted conditions. Horticultural plant journal, 6(3), 123-131.
2. Kusumawati, A., Hanudin, E., Purwanto, B. H., & Nurudin, M. (2020). Composition of organic C fractions in soils of different texture affected by sugarcane monoculture. Soil Science and Plant Nutrition, 66(1), 206-213.
3. De Freitas, P. L., Zobel, R. W., & Synder, V. A. (1999). Corn root growth in soil columns with artificially constructed aggregates. Crop Science, 39(3), 725-730.
4. Xia, S. Q., Zhao, H. T., Wu, Y. F., Han, S. W., Mi, W. H., Kang, Y. J., ... & Feng, K. (2020). Effect of feeding conditions on the degradation of tetracycline in sewage sludge by earthworm. Biochemical Engineering Journal, 160, 107608.
5. Mijangos, I., & Garbisu, C. (2010). Consequences of soil sampling depth during the assessment of the effects of tillage and fertilization on soil quality: a common oversight. Soil and Tillage Research, 109(2), 169-173.
6. Paz-Ferreiro, J., Fu, S., Méndez, A., & Gascó, G. (2014). Interactive effects of biochar and the earthworm Pontoscolex corethrurus on plant productivity and soil enzyme activities. Journal of Soils and Sediments, 14, 483-494.
7. Rochette, P., Ellert, B., Gregorich, E. G., Desjardins, R. L., Pattey, E., Lessard, R., & Johnson, B. G. (1997). Description of a dynamic closed chamber for measuring soil respiration and its comparison with other techniques. Canadian journal of soil science, 77(2), 195-203.
8. Parkin, I. P. (1996). Solid state metathesis reaction for metal borides, silicides, pnictides and chalcogenides: ionic or elemental pathways. Chemical Society Reviews, 25(3), 199-207.
9. Spedding, T. A., Hamel, C., Mehuys, G. R., & Madramootoo, C. A. (2004). Soil microbial dynamics in maize-growing soil under different tillage and residue management systems. Soil Biology and Biochemistry, 36(3), 499-512.
10. Saba, M., & Karaca, U. Ç. (2023). Exploring the Physical,

Chemical, and Biological Properties of Soils from Different Regions Classified into Different Textural Classes.
11. Serra-Wittling, C., Houot, S., & Barriuso, E. (1995). Soil enzymatic response to addition of municipal solid-waste compost. Biology and Fertility of Soils, 20, 226-236.
12. Plaza, C., Hernández, D., Garcia-Gil, J. C., & Polo, A. (2004). Microbial activity in pig slurry-amended soils under semiarid conditions. Soil Biology and Biochemistry, 36(10), 1577-1585.
13. Brady, N. C., & Weil, R. R. (2004). Elements of the nature and properties of soils.
14. Trasar-Cepeda, C., Leirós, M. C., & Gil-Sotres, F. (2008). Hydrolytic enzyme activities in agricultural and forest soils. Some implications for their use as indicators of soil quality. Soil Biology and Biochemistry, 40(9), 2146-2155.
15. Sugihara, S., Funakawa, S., Kilasara, M., & Kosaki, T. (2010). Effect of land management and soil texture on seasonal variations in soil microbial biomass in dry tropical agroecosystems in Tanzania. Applied Soil Ecology, 44(1), 80-88.
16. Vinhal-Freitas, I. C., Corrêa, G. F., Wendling, B., Bobuľská, L., & Ferreira, A. S. (2017). Soil textural class plays a major role in evaluating the effects of land use on soil quality indicators. Ecological indicators, 74, 182-190.
17. Bouyoucos, G. J. (1951). A recalibration of the hydrometer method for making mechanical analysis of soils 1. Agronomy journal, 43(9), 434-438.
18. Isermeyer, H. (1952). Eine einfache Methode zur Bestimmung der Bodenatmung und der Karbonate im Boden. Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde, 56(1-3), 26-38.
19. Hoffmann, G. G., & Teicher, K. (1961). Ein kolorimetrisches verfahren zur bestimmung der ureaseaktivität in Böden. Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde, 95(1), 55-63.
20. Thalmann, A. (1966). Zur Bestimmung der Dehydrogenaseaktivität im Boden Mittels TTC (Triphenyltetrazoliumchlorid). Soil Biol., 6, 46-47.
21. MA, T. (1970). Arylsulphatase activity of soils. In Soil Sci. Soc. Am. Proc. (Vol. 34, pp. 427-429).
22. Zhu, Y., Guo, B., Liu, C., Lin, Y., Fu, Q., Li, N., & Li, H. (2021). Soil fertility, enzyme activity, and microbial community structure diversity among different soil textures under different land use types in coastal saline soil. Journal of Soils and Sediments, 21, 2240-2252.
23. Atman, S. (2022). Measuring the Electrical Conductivity of Soils Located in the South of the in Cost Line.
24. Stutler, K. D. (2019). Soil Health Assessment in Reclaimed Mine Soils. West Virginia University.
25. Eivazi, F., & Zakaria, A. (1993). β-Glucosidase activity in soils amended with sewage sludge. Agriculture, ecosystems & environment, 43(2), 155-161.
26. Dick, R. P. (1994). Soil enzyme activities as indicators of soil quality. Defining soil quality for a sustainable environment, 35, 107-124.
27. Tosun, F., Manga, I., Altın, M., & Serin, Y. (1975). A research on arid rangeland improvement in Erzurum conditions. TUBITAK V. In Science Congress. Agriculture and Forestry Group.
28. Makoi, J. H., & Ndakidemi, P. A. (2008). Selected soil enzymes: examples of their potential roles in the ecosystem. African Journal of Biotechnology, 7(3).
29. Versaw, W. K., & Harrison, M. J. (2002). A chloroplast phosphate transporter, PHT2; 1, influences allocation of phosphate within the plant and phosphate-starvation responses. The Plant Cell, 14(8), 1751-1766.
30. Irmak Yilmaz, F., & Ergun, Y. A. (2019). Impact of biochar and animal manure on some biological and chemical properties of soil. Appl. Ecol. Environ. Res, 17, 8865-8876.
31. Beck, T. H. 1971. Measuring the catalase activity of soils. Journal of Plant Nutrition and Soil Science. 130:68–81. doi:10.1002/jpln.19711300108.
32. Bremner, J. M., & Hauck, R. D. (1982). Advances in methodology for research on nitrogen transformations in soils. Nitrogen in agricultural soils, 22, 467-502.
33. Woś, B., Józefowska, A., Likus-Cieślik, J., Chodak, M., & Pietrzykowski, M. (2021). Effect of tree species and soil texture on the carbon stock, macronutrient content, and physicochemical properties of regenerated postfire forest soils. Land Degradation & Development, 32(18), 5227-5240.
34. Fernandes, S. A. P., Bettiol, W., & Cerri, C. C. (2005). Effect of sewage sludge on microbial biomass, basal respiration, metabolic quotient and soil enzymatic activity. Applied Soil Ecology, 30(1), 65-77.
35. Frankenberger Jr, W. T., Johanson, J. B., & Nelson, C. O. (1983). Urease activity in sewage sludge-amended soils. Soil Biology and Biochemistry, 15(5), 543-549.
36. Ge, N., Wei, X., Wang, X., Liu, X., Shao, M., Jia, X., ... & Zhang, Q. (2019). Soil texture determines the distribution of aggregate-associated carbon, nitrogen and phosphorous under two contrasting land use types in the Loess Plateau. Catena, 172, 148-157.
37. Cetin Karaca, U., Chalabee, O. A. H., & Saba, M. (2023). The Effect of Sheep Wool Fertilizer on Some Biochemical Properties of a Clay Loam Soil. Communications in Soil Science and Plant Analysis, 54(1), 48-61.
38. Hoffman, H. S., Searle, J. L., Toffey, S., & Jr, F. K. (1966). BEHAVIORAL CONTROL BY AN IMPRINTED STIMULUS 1. Journal of the Experimental Analysis of Behavior, 9(3), 177-189.
39. Lindsay, W. L., & Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil science society of America journal, 42(3), 421-428.
40. Olsen, S. R. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.
41. Richards, L. A. (Ed.). (1954). Diagnosis and improvement of saline and alkali soils (No. 60). US Government Printing Office.
42. Skujiņš, J., & Burns, R. G. (1976). Extracellular enzymes in soil. CRC critical reviews in microbiology, 4(4), 383-421.
43. Smith, H. W., & Weldon, M. D. (1941). A comparison of some methods for the determination of soil organic matter. Soil Science Society of America Journal, 5(C), 177-182.
44. Soltanpour, P. N., Workman, S. M., & Schwab, A. P. (1979).

Use of inductively-coupled plasma spectrometry for the simultaneous determination of macro-and micronutrients in NH4HCO3-DTPA extracts of soils. Soil Science Society of America Journal, 43(1), 75-78.

45. Tabatabai, M. A. (1977). Effects of trace elements on urease activity in soils. Soil Biology and Biochemistry, 9(1), 9-13.
46. Staff, U. S. L. (1954). Diagnosis and improvement of saline and alkali soils. Agriculture handbook, 60, 83-100.