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Exploring Catalase Activity as A Biological Indicator in Degraded Soils

Degrade Topraklarda Katalaz Aktivitesinin Biyolojik Bir Gösterge Olarak Araştırılması

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EXPLORING CATALASE ACTIVITY AS A BIOLOGICAL INDICATOR IN DEGRADED SOILS

ABSTRACT

This study examines the relationship between catalase activity in degraded soils and soil properties, and addresses its potential as an indicator of soil health and productivity. Catalase, a key enzyme reflecting microbial activity and soil aeration, has been analyzed in 30 soil samples collected from the disturbed surface layer (0-15 cm depth) of erosion-prone areas characterized by rubble accumulation on hill slopes and soil compaction in foot slopes. The soil in the study area is classified as Typic Xerortent. Catalase enzyme activity in the soil samples varied between 10.4 and 48 µl O_2 g^{-1} dry soil. In addition to catalase, the physicochemical properties of the soil were also assessed, including pH, electrical conductivity, organic matter content, and texture. Nutrient contents, including nitrogen (0.046-0.239 g N 100 g^{-1}), phosphorus (1.77-20.05 µg P g^{-1}), and potassium (0.01-3.31 meq K 100 g^{-1}), were also measured. A positive correlation was observed between catalase activity and potassium and phosphorus levels, but the relationship with nitrogen was statistically insignificant. These findings suggest that catalase activity can serve as a biological indicator for the early detection of degradation in soils at risk of erosion. The study provides valuable insights into the impact of erosion on soil biochemistry and highlights the role of catalase in assessing soil health and guiding sustainable land management practices.

Keywords: Catalase Activity, Macro Nutrients, Soil Degradation and Enzyme.

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DEGRADE TOPRAKLARDA KATALAZ AKTİVİTESİNİN BİYOLOJİK BİR GÖSTERGE OLARAK ARAŞTIRILMASI

ÖZ

Bu çalışma, degrade topraklardaki katalaz aktivitesi ile toprak özellikleri arasındaki ilişkiyi incelemekte ve toprak sağlığı ve verimliliğinin bir göstergesi olarak potansiyelini ele almaktadır. Mikrobiyal aktiviteyi ve toprak havalanmasını yansıtan anahtar bir enzim olan katalaz, toprak sıkışması ile karakterize edilen ayak yamaçlarındaki ve tepe yamaçlarında moloz birikimi ile karakterize edilen erozyona hassas alanların bozulmuş yüzey tabakasından (0-15 cm derinlik) toplanan 30 toprak örneğinde analiz edilmiştir. Çalışma alanındaki toprak Tipik Xerortent olarak sınıflandırılmıştır. Toprak örneklerinde katalaz enzim aktivitesi 10.4 ile 48 µl O_2 g^{-1} kuru toprak arasında değişiklik göstermiştir. Katalazın yanı sıra toprak fizikokimyasal özellikleri de değerlendirilmiştir; bunlar pH, elektriksel iletkenlik ve organik madde içeriği gibi özelliklerdir. Azot (0.046-0.239 g N 100 g^{-1}), fosfor (1.77-20.05 µg P g^{-1}) ve potasyum (0.01-3.31 meq K 100 g^{-1}) da dahil olmak üzere besin içerikleri de ölçülmüştür. Katalaz aktivitesi ile potasyum ve fosfor seviyeleri arasında pozitif bir korelasyon gözlemlenmiştir, ancak azot ile ilişki istatistiksel olarak anlamsızdır. Bu bulgular, katalaz aktivitesinin erozyon riski taşıyan topraklarda bozulmanın erken tespiti için bir biyolojik gösterge olarak hizmet edebileceğini öne sürmektedir. Çalışma, erozyonun toprak biyokimyası üzerindeki etkisine dair değerli bilgiler sağlamakta ve katalazın toprak sağlığını değerlendirme ve sürdürülebilir arazi yönetimi uygulamalarını yönlendirmedeki rolünü vurgulamaktadır.

Anahtar Kelimeler: Katalaz Aktivitesi, Makro Besinler, Toprak Bozulması ve Enzim.

1. INTRODUCTION

Sustainable land management in semi-arid regions is crucial for enhancing soil quality and mitigating the negative impacts of improper soil management (Shrestha, 2015). Low levels of soil organic matter in these regions can lead to persistent deterioration of soil quality. Soil organic matter plays a significant role in countering the negative impacts of improper soil management and use (Adams, 1973). Additionally, soil moisture is vital for vegetation growth and ecosystem sustainability in semi-arid regions (Zhao et al., 2018). Furthermore, the creation of permanent planting basins has been identified as a common soil and water conservation practice that enhances water harvesting and precision application of fertility amendments, thereby improving soil quality (Marumbi et al., 2023). The preservation of soil quality is crucial, especially in ecosystems where human activities exacerbate soil degradation and desertification. Human activities, such as unsustainable soil management practices, pollution, waste disposal, and increasing extreme weather events, have led to widespread and increasing rates of soil degradation globally (Ma et al., 2022; Dengiz and Demirağ-Turan, 2023; Kaya et al., 2023). Erosion stands as one of the principal causes of such degradation. Consequently, it is vital to investigate sensitive biomarkers linked to the degradation and desertification of soils.

The slow alteration of soil organic matter levels necessitates long observation periods to detect changes resulting from exposure. Consequently, research is being conducted to demonstrate that soil biological properties can serve as early and sensitive indicators of soil ecological stress or restoration (Kandziora-Ciupa et al., 2021). This is particularly important as soil degradation and restoration processes are complex and can take a long time to manifest observable changes in soil organic matter levels (Rodríguez et al., 2018; Ramazanoglu, 2023). The levels of enzymes and organic matter strongly impact soil biological properties, making them potential indicators of soil ecological stress or restoration (Kandziora-Ciupa et al., 2021). Additionally, the recovery of soil organic matter and soil biological properties following disturbances such as wildfires or land use changes can provide insights into the potential use of soil biological properties as early indicators of soil ecological stress or restoration (Rodríguez et al., 2018; Baligh et al., 2021; Panico et al., 2022; Kimmell, 2023; Wu et al., 2023).

Soil biological properties, including microbial activity, microbial biomass, and enzyme activities, are sensitive to changes in soil organic matter and can be used as indicators of soil ecological stress or restoration (Marshall et al., 2018; Baligh et al., 2021; Kandziora-Ciupa et al., 2021; Sainju et al., 2021; Panico et al., 2022; Kimmell, 2023; Wu et al., 2023). For instance, the soil microbial community responds rapidly to changes in environmental conditions, indicating its potential as an early indicator of soil ecological stress or restoration (Mukherjee et al., 2022). Furthermore, the addition of organic matter directly affects soil carbon, nitrogen, and phosphorus, which are crucial components of soil biological properties and indicators of soil health (Xuefeng et al., 2023). The impact of vegetation restoration on soil quality and the soil microbial community also highlights the potential of soil biological properties as early indicators of soil ecological stress or restoration (Guan and Fan, 2020; Liu et al., 2021; Wu et al., 2023).

Soil enzyme activity shows a considerable correlation with the soil's physical and chemical properties. These enzyme activities are early indicators of shifts in the degree of soil degradation and variations in the intensity of biological processes (Adetunji et al., 2017; Geng et al., 2022; Singh et al., 2022). Soil biological and biochemical parameters, thus, offer a means to assess the extent of soil degradation.

The evaluation of catalase enzyme activity relies on the principle of determining the released O_2. Catalase is an enzyme present in most aerobic and facultative anaerobic bacteria, but notably absent in obligate anaerobic bacteria (Kim et al., 2016). This absence of catalase in obligate anaerobic bacteria is a key factor in their ability to cope with changing oxygen levels during infection, as they cannot survive in the presence of oxygen (Andre et al., 2021). Additionally, the presence of catalase in aerobic and facultative anaerobic bacteria is a crucial factor in their ability to scavenge reactive oxygen species, thereby minimizing the effects of free radicals (Watthanasakphuban et al., 2023). There is a significant correlation between catalase activity and soil organic carbon content (Hu et al., 2020). Hydrogen peroxide (H_2O_2), induced by various processes, is toxic to cells. Oxygenated cells generally contain enzymes that convert superoxide into molecular oxygen and H_2O_2.

$$2O_2^- + 2H^+ \rightarrow H_2O_2 + O_2$$

Enzyme systems such as L- and D-amino acid oxidases, which involve prosthetic groups like FMN or FAD, catalyze the removal of oxidative amino groups from amino acids.

L-Amino acid + H_2O + E-FMN → α-Keto acid + NH_3 + E-$FMNH_2$

D-Amino acid + H_2O + E-FAD → α-Keto acid + NH_3 + E-$FADH_2$

The reduced forms of these oxidases facilitate the re-oxidation reaction with molecular oxygen, producing H_2O_2.

E-$FMNH_2$ + O_2 → E-FMN + H_2O_2

E-$FADH_2$ + O_2 → E-FAD + H_2O_2

Catalase enzyme activity is an indicator of microbial activity in soil and is influenced by the soil's physical, chemical, and biological properties, all of which play crucial roles (Ekberli & Kizilkaya, 2006). Low microbial activity results in a decrease in both macro- and micro-organisms, impacting the associated soil food-web dynamics. High catalase enzyme activity, which catalyzes the degradation of H_2O_2, indicates favorable soil conditions for aerobic microflora (Lemanowicz et al., 2020).

Intracellular catalase enzyme (EC 1.11.1.6) is a vital heme-containing enzyme that plays a crucial role in cellular defense mechanisms by catalyzing the decomposition of hydrogen peroxide (H_2O_2) into water and molecular oxygen (Chakravarti et al., 2015). Reactive oxygen species (ROS), which are formed as by-products during aerobic respiration in various cellular systems, represent a cost that aerobic organisms must bear due to the high efficiency of O_2-dependent respiration metabolism (Mogen et al., 2017). The production of ROS can lead to oxidative stress, which can have detrimental effects on cellular components and functions (Imlay, 2015). Soil catalase activity has been found to exhibit significant correlations with certain soil chemical properties, including macro and micronutrient contents, suggesting a potential association between catalase activity and soil productivity (Sun et al., 2019).

The role of catalase in cellular defense against oxidative stress is well-documented. Catalase plays a critical role in protecting cells from the harmful effects of ROS, which can cause oxidative damage to cellular components such as lipids, proteins, and DNA. The ability of catalase to decompose H_2O_2 into water and oxygen helps to mitigate the potential cytotoxic effects of ROS, thereby contributing to the maintenance of cellular redox homeostasis (Chakravarti et al., 2015).

The interplay between soil catalase activity and various soil chemical properties, such as macro and micronutrient concentrations, is indicative of a potential relationship between this enzyme activity and soil fertility (Sun et al., 2019). Zhang et al. (2020), have further explored this by examining soil enzyme behaviors under varying flooding conditions, uncovering their sensitivity to alterations in the soil's active organic carbon makeup. This finding underscores the significant role that soil chemical characteristics play in governing enzyme activities.

The health of the soil is critically influenced by the properties of its microorganisms and their enzymes. These biological components are quick to react to environmental shifts, especially those leading to degradation, more so than soil's physical or chemical properties. Support this assertion, pointing out those factors like plant types, fertilization methods, and land management strategies exert considerable influence on the soil's microbial biomass and enzymatic activity. A pivotal concern in this context is soil erosion, identified globally as a primary driver of soil degradation (Poesen, 2017; Fokeng et al., 2020; Wei et al., 2024).

In concluding, it is evident that catalase, an enzyme pivotal in defending cells against oxidative stress, is subject to various environmental and cellular influences. The link between its activity in soil and the soil's chemical makeup not only underscores its potential effect on soil productivity but also on nutrient cycling processes. The adverse effects of soil erosion, a significant ecological challenge, extend to soil microbial attributes and enzyme activities. Hou et al. (2014) document a marked decline in microbial populations, diversity, biomass, and enzymatic activities associated with soil erosion. Erosion inversely affects microbial activity, primarily due to soil structure degradation, reduced aggregate stability, and nutrient loss (Dungait et al., 2013; Li et al., 2015; Xiao et al., 2018). The erosion also diminishes organic matter and humus in topsoil, thereby impairing conditions necessary for proper aeration, further impacting microbial activity (Xu et al., 2020). Consequently, erosion establishes a scenario where it is inversely proportional to microbial activity.

The objectives of this study were to (i) document the differentiation in catalase activity (CA) among thirty soil samples collected from the Avsar Campus, Kahramanmaras Sutcu Imam University, which is an eroded and erosion research area in Turkey, and (ii) determine the relationships between CA and the NPK (nitrogen, phosphorus, potassium) content of these soils. To this end, 30 soil samples were collected from the disturbed surface layer (0-15 cm depth) of the study area. The primary aim of this study is to evaluate the potential of catalase activity as a biological indicator for the early detection of degradation in eroded soils at risk of soil degradation and to understand its relationship with soil plant nutrient elements.

2. MATERIAL AND METHOD

Soil samples were collected from the plot area of Avsar Campus, Kahramanmaras Sutcu Imam University (KSU), approximately 10 km west of the Kahramanmaras city center, Turkey (Figure 1). The sampling operation was conducted during the winter months when the soil surface was snow-covered. The study area is slated to be transformed into the Erosion Research Area in the near future (KSU-ERA).

Figure 1. The study area in KSU on the Türkiye map (Google Earth Pro, 2024)

The study area is located at an elevation of 483-513 meters above sea level (Figure 2). The average annual temperature and precipitation are 16.5 °C and 710 mm, respectively. The soil temperature and moisture regimes are classified as mesic and xeric, respectively. The soil has been classified as Typic Xerorthent (Gundogan et al., 1997). Despite its relatively small size, the area exhibits varied soil properties due to differences in plant cover (ranging from weak forest and shrub to grass or bare surface) and topographic aspects. Notably, there is significant soil compaction in the foot slope and rubble accumulation on the hillslope.

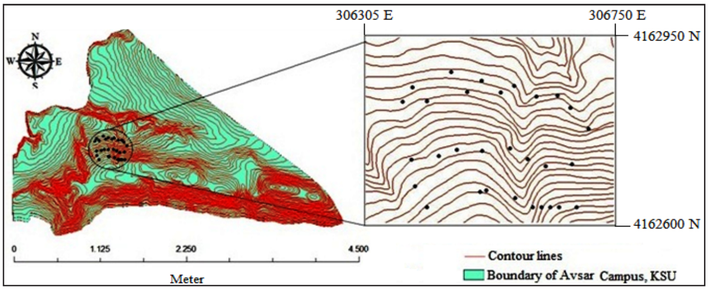

Figure 2. Soil sampling field on the contour topographic map of Avsar Campus (Yakupoğlu & Gündoğan, 2015)

For the purpose of this study, 30 soil samples were collected from the disturbed surface layer (0-15 cm depth) of the study area. Field-moist samples from both sampling batches were manually crumbled and sieved (<2 mm) to remove root material. Each sample was thoroughly mixed and stored at field humidity in polyethylene bags at 4 °C until analysis. The samples were transported to the laboratory on the same day and refrigerated at 4 °C for no longer than 72 hours prior to analysis.

Catalase Activity (CA) was measured using the method described by Beck (1971). For this procedure, 10 ml of phosphate buffer (pH 7) and 5 ml of a 3% H_2O_2 substrate solution were added to 5g of soil. The volume (ml) of O_2 released within 3 minutes at 20 °C was determined. Three replicates of each sample were tested. Controls were similarly tested but with the addition of 2 ml of 6.5% (w/v) NaN_3. Results were expressed as µl O_2 g^{-1} dry soil.

One sample was taken from each point, but the analyzes were carried out in three replicates on that sample. All results are reported as the mean value of three replicate determinations, calculated on an oven-dry basis. Soil moisture content was determined by the weight loss after drying the soil at 105 °C for 24 hours. Statistical analyses were performed using the TARIST software package. Physico-chemical analyses were conducted on air-dried samples, stored at room temperature, after removing crop residues, root fragments, and rocks larger than 2 mm in diameter. Selected soil physico-chemical properties are presented in Table 1.

Table 1. Procedures for analyzing general soil properties of study soil samples (Kacar, 1994; John Ryan, 2001)

Analyses	Methods
Texture	Bouyoucos Hydrometer
pH	1:1 (w/v) pH-meter
EC	1:1 (w/v) EC-meter
CaCO3, g kg^{-1}	Scheibler calcimeter
SOM, g kg^{-1}	Walkey-Black method
Total N, %	Kjeldahl method
Si, g kg^{-1}	Acid amonium oxalate
P, µg g^{-1}	Flamefotometric
Av- P, µg g^{-1}	Olsen method
Ex- K, cmolc kg^{-1}	1 N NH_4OAc extraction

2.1. Statistical Analysis

In this study, correlation analysis was used to examine the relationships between two variables. Specifically, we investigated the interactions between CA-N, CA-P, and CA-K. The R^2 (coefficient of determination) values were calculated to assess the explanatory power of these interactions on the dependent variable. A higher R^2 value indicates a stronger relationship and greater explanatory power. The statistical analysis was conducted using TARIST (1994) statistical software.

3. RESULTS AND DISCUSSION

Descriptive statistics of the study soils are presented in Table 2. According to this table, the maximum clay, silt, and sand contents were found to be 264, 607, and 654 g kg^{-1} respectively, while the minimum values were 38, 258, and 197 g kg^{-1} in the same order. Soil Organic Matter (SOM) and $CaCO_3$ contents ranged between 9.8-47.0 and 6.6-224 g kg^{-1}, respectively. Cation Exchange Capacity (CEC) values varied from 22.78 to 97.60 cmolc kg^{-1}. The mean N, P, and K contents of the soils were determined as 0.124%, 8.36 µg g^{-1}, and 1.77 cmolc kg^{-1}, respectively. The CA of the study soils was measured at a minimum of 10.4 µl O_2 g^{-1} and a maximum of 48.0 µl O_2 g^{-1}.

Table 2. Descriptive statistics of study soils

Analyses	Min.	Max.	Mean	SD
Clay, g kg^{-1}	38	264	117	50
Silt, g kg^{-1}	258	607	449	78
Sand, g kg^{-1}	197	654	435	105
SOM, g kg^{-1}	9.8	47.2	24.7	9.6
Salt, g kg^{-1}	0.09	2.05	0.90	0.38
CaCO3, g kg^{-1}	6.6	224	38.9	52.5
Total N, %	0.046	0.239	0.124	0.006
Available P, µg g^{-1}	1.77	20.05	8.36	0.45
Exchangable K, cmolc kg^{-1}	0.01	3.31	1.77	0.09
CA, µl O_2 g^{-1}	10.4	48.0	27.21	1.04

According to the variance analysis results, it is noteworthy that soils are statistically different in terms of CA, N, P, and K contents ($P<0.01$). As shown in Figure 3, which displays the measured CA values of the soils, Soil 21 had the highest CA value, while Soil 7 had the lowest. The values for other soils varied between these extremes. This diversity is likely associated with the natural variability in the non-agricultural land of the research area, as it is known that catalase enzyme activity is influenced by soil physical conditions. Indicators have been developed between soil physical properties and soil erodibility indices. There are strong relationships between soil erodibility indices and erosion. Soil physical properties such as clay percentage, bulk weight, structural stability index, soil compaction, air-water balance and catalase enzyme activity which is in direct interaction with oxygenation are affected by soil physical properties (Zhang et al., 2004; Nandi and Luffman, 2012; Wu et al., 2018). Lemanowicz et al. (2020) reported that differences in biochemical activity in soil are based on natural biotic and abiotic processes.

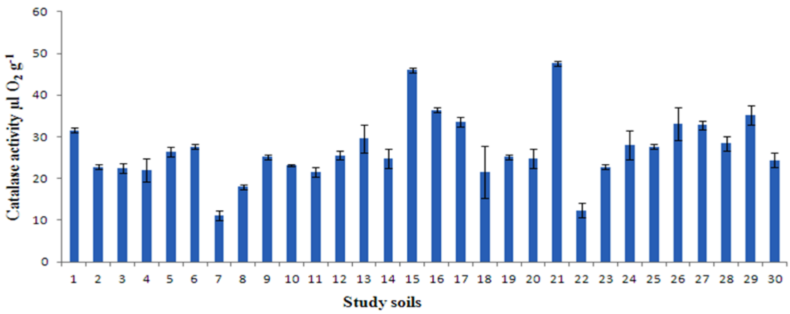

Figure 3. CA values of soils

Xu et al. (2017) also demonstrated that soil microbial activity (except for SA and PA) showed minimal changes in the 20-50 cm soil layers. Soil microbial activity is positively correlated with nutrient availability. Nutrients from root exudates and litter, which are directly acquired by the topsoil, play a crucial role. Recent studies have revealed that soil microbial activity is inversely correlated with soil depth (Könönen et al., 2018; Xu et al., 2020). Suitable ventilation conditions in the topsoil are highly important for increasing microbial activity, as is the abundance of organic matter (Sinha et al., 2009; Xu et al., 2020).

Soil compaction or loosening alters the oxygen amount in the soil and thereby affects CA. The impact of soil bulk density on enzyme activities can be linked to its effects on other soil physical properties, such as total porosity, oxygen content, diffusion rate, and water infiltration rate, all of which influence microbial activity (Li et al., 2002). In addition, soil chemical properties may be related to catalase activity. The relationships between CA and NPK contents of the soils are illustrated in Figure 4. The R^2 value of the CA-N content interaction was calculated as low (R^2 = 0.0002), while the R^2 values for CA-P and CA-K interactions were found to be relatively high (R^2s = 0.81 and 0.61).

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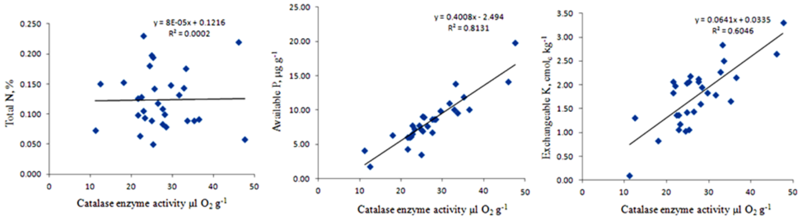

Figure 4. Simple relationships between CA and soil macronutrient contents

Our study has elucidated a critical inverse relationship between soil nutrient deficiencies and catalase enzyme activity, particularly in soils undergoing various degrees of degradation. This finding is pivotal in understanding the complex interactions within soil ecosystems, especially in the context of degradation and nutrient dynamics.

Catalase, a key enzyme in soil biochemistry, acts as an indicator of soil health and fertility. Our observations that catalase activity diminishes in nutrient-deficient and degraded soils align with the research conducted by Sun et al. (2019), who noted an increase in soil catalase activity following long-term vegetation restoration. This parallel suggests that the presence of robust vegetation can counteract the negative impacts of soil degradation, subsequently enhancing soil fertility and microbial diversity. This correlation underscores the role of biotic factors, particularly vegetation, in maintaining soil enzyme activities and overall soil health.

Further, our study presents a nuanced view of soil nutrient interactions with catalase activity. The observed linear inverse relationship between available phosphorus (P) and exchangeable potassium (K) levels with catalase activity contrasts with the non-linear relationship with total nitrogen (N) percentages. This indicates that while P and K deficits are directly linked to reduced catalase activity, N dynamics in the soil may be influenced by other factors, such as organic matter mineralization and biotic interactions. This complexity in nutrient-enzyme interactions echoes the findings of Chang et al. (2007), who highlighted the influence of organic fertilizer application on soil enzyme activities and microbial populations.

In analyzing the broader context of soil degradation, our study expands upon the work of Achuba and Okoh (2014) and Wu et al. (2010), who found that external factors like petroleum products and dimethomorph significantly alter soil catalase activities. Moreover, Kuscu and Karaöz (2021) revealed that land use significantly influences catalase activity, with forest soils exhibiting the highest and agricultural lands the lowest activities. These findings collectively indicate that external anthropogenic factors and land use patterns critically impact catalase enzyme activity, further complicating the relationship between soil health and enzyme function.

Contrarily, Zhang et al. (2016) reported no significant correlation between catalase activity and soil nutrients with the addition of straw, suggesting that the impact of nutrient deficiencies on catalase activity may not be direct or uniform across different soil conditions. This is supported by Liu et al. (2016), who demonstrated that soil enzyme activity, including catalase, is affected by various factors like ryegrass growth and soil pollutants. Moreover, the study by Li et al. (2014) suggests that catalase activity is related to the metabolic activity of aerobic organisms and has a significant correlation with the content of organic carbon, which can be affected by soil erosion and degradation. The work of Galiulin and Galiulina (2015) also supports this, showing that biological preparations for soil remediation influence catalase and other enzymes' activities. Additionally, the study by Lemanowicz et al. (2018) indicated that the activity of soil enzymes, including catalase, decreased with increasing electrical conductivity, suggesting a potential impact of soil salinity on enzyme activity.

In summary, our study underscores the intricate interplay between soil health, nutrient availability, and enzyme function. Soil degradation, influenced by factors like petroleum products, land use, soil pollutants, and soil salinity, leads to reduced catalase enzyme activity. This highlights the need for a comprehensive understanding of soil ecosystem dynamics, particularly in the face of increasing environmental stressors and anthropogenic activities.

The intricate relationship between soil degradation, nutrient status, and catalase enzyme activity observed in our study also sheds light on the broader implications of soil health in agricultural productivity and ecological sustainability. This aspect is critical, given the escalating challenges of soil erosion, nutrient depletion, and environmental pollution, which pose a threat to food security and ecosystem stability.

The reduction in catalase activity in degraded soils, as indicated in our study, can be interpreted as a reflection of decreased microbial activity and overall soil biological health. This aligns with the findings of Karaca et al. (2011) who emphasized the role of soil enzymes as bioindicators of soil health and quality. The decrease in catalase activity due to nutrient deficiencies indicates a potential decline in the soil's capacity to detoxify hydrogen peroxide, which is crucial for maintaining microbial vitality and organic matter decomposition rates.

Soil erosion is a significant contributor to soil degradation, leading to a reduction in soil fertility and nutrient deficiencies (Susanti et al., 2019). This degradation is often caused by factors such as wind erosion, water-logging, salinity/alkalinity, and water erosion (Raina et al., 2009). It is important to note that soil erosion is a multifaceted process influenced by various factors, including human activities and climate change. Human activities, such as agriculture and land use changes,

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have been shown to have a significant impact on soil erosion and subsequently on soil enzymatic activities, including catalase (Nedyalkova et al., 2017; Huang et al., 2020; Wang et al., 2020; Li et al., 2021; Steinhoff-Knopp et al., 2021). As a result, the reduction in soil quality can lead to a decline in catalase enzyme activity, which is an important indicator of soil fertility (Li et al., 2014).

Furthermore, the impact of soil degradation on nutrient deficiencies and enzyme activity has been studied in various regions, including Indonesia (Susanti et al., 2019), Sri Lanka (Jayasekara et al., 2018), and Europe (Žížala et al., 2017). These studies emphasize the widespread nature of soil erosion as a significant form of soil degradation, affecting soil properties and enzyme activities. Additionally, the review by Maina et al. (2018) highlights the threat of soil erosion to sustainable soil productivity and food security, further underlining the importance of addressing erosion-induced soil degradation.

In conclusion, our study contributes to the growing body of literature on soil degradation, nutrient dynamics, and enzyme activity. It underscores the need for an integrated approach in soil health assessment and management, considering both biotic and abiotic factors. As soil degradation continues to be a global concern, research that deepens our understanding of these complex interactions remains essential for sustainable soil management and environmental conservation. soil erosion is a widespread and significant form of soil degradation that can lead to nutrient deficiencies and a reduction in catalase enzyme activity. The impact of soil degradation on enzyme activity and soil fertility is influenced by various factors, including land use, organic carbon content, and specific soil nutrients. Addressing soil erosion is crucial for maintaining soil quality and enzyme activity, which are essential for sustainable agricultural productivity. We recommend controlled laboratory and greenhouse experiments to accurately determine these relationships and highlight the importance of soil enzyme activities as indicators of soil quality and biological activities. Thus, understanding the dynamics of soil enzymes, like catalase, in relation to nutrient status is vital for developing effective soil restoration and management practices.

4. CONCLUSION

The presence of macronutrients crucial for plant nutrition and microbial activity in surface soils is important for agricultural purposes. In erosive soils, available nutrient cycles are adversely affected. Soil microbial activity is also an indicator of soil health. This study reveals that the catalase enzyme activities of soils are related to their chemical properties, such as N, P, and K concentrations, in the plot area of Avsar Campus, Kahramanmaras, Turkey. It was found that CA was higher in samples with elevated available P content, exhibiting a positive and linear relationship. Among the soil samples, as the exchangeable K content increased, CA also increased, showing a positively linear relationship with exchangeable K. Since the interaction between total N and CA was very low, a definitive relationship between them could not be established. The findings of this study, demonstrating varied catalase enzyme activity across different points of the area, should be considered in the planning of this location as an Erosion Research Area. Regular monitoring of soil enzyme activities, including catalase activity, should be conducted to detect early signs of soil degradation. This can help in timely interventions to prevent further soil deterioration. Conduct controlled laboratory and greenhouse experiments to better understand the relationships between soil enzyme activities and soil physical properties. This can provide more detailed insights into the mechanisms driving soil health and inform more effective soil management strategies.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethic comity approval.

Author Contribution Rates

Design of Study: FŞHT(%50), TY(%50)

Data Acquisation: FŞHT(%45), MD(%45), TY(%10)

Data Analysis: FŞHT(%30), MD(%10), TY(%60)

Writing Up: FŞHT(%85), MD(%5), TY(%10)

Submission and Revision: FŞHT(%90), TY(%10)

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