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ARTICLE

Soil Biological Characteristics in the Al-Haidariyya Sub-District, Iraq

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ABSTRACT

Finding microorganism-rich soils has become popular in recent years. Through natural mechanisms, these bacteria can protect plants from diseases and give critical nutrients. Ecologically and economically sustainable food production is essential to meet global demand. This article highlights soil microorganisms' function in the global carbon cycle and their principal identification methods. Identifying and assessing soil ecosystems based on land use is crucial. This study examined soil microbiology in Al-Haydariyya sub-district. Although new study reveals that soil populations of Escherichia coli can also be found in tropical, subtropical, and temperate locations, their presence in water is usually used to indicate feces contamination. The results of the study showed that by examining a total of 16 soil samples taken from a depth ranging from 0–30 cm, the research encompassed three distinct soil types: riverbank soil, river basin soil, and plateau soil. The number of *E. coli* bacteria in the overlapping soil was recorded at 21×10^5 cells ml^{-1}. Regarding the minimum occurrence, it pertained to Staphylococcus bacteria found in the shoulder soil during January. The bacterial count for sample 1 was noted at 1×10^5 cell ml^{-1}, while samples 2 and 3 did not exhibit noteworthy bacterial activity. This knowledge is necessary to guide the logical modification of the plant-soil system in order to favor the organisms or physiologies that are most crucial for encouraging the storage of carbon in agricultural soil.

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1. Introduction

The soil biota is an essential component of the soil ecosystem and actively contributes to soil formation by altering the physicochemical properties of soil. The soil contains the greatest species variety in the majority of terrestrial ecosystems and is home to all major invertebrate groups. Although nothing is known about many soil taxa, new species have been found and described in urban settings [1]. Since the majority of soil organisms are a part of the decomposer food chain, their primary ecological roles are nutrient mobilization and detritus digestion. Due to its tremendous complexity, the soil food web is currently a major area of study for soil ecology. The soil food chain is seen by many soil ecologists as being extremely redundant [2]. Changes in the physical and chemical characteristics of soil have a direct impact on its biological qualities. In fact, alterations in bulk density, porosity, aeration, soil organic matter, and acidity would alter the biological components of the soil and interfere with microbial activity [3, 4]. It has been proposed that enzyme activity serves as sensitive markers of the biological characteristics of soil [5]. The most crucial natural resources of a watershed in a rainfed agro-ecosystem are soil, water, and production systems; these resources must coexist with the environment for the production systems to be sustainable [6]. In addition to boosting output, healthy soil is necessary for the agro-ecology to deliver the services and advantages that come from controlling ecosystem processes. Additionally, soil is essential for supporting agro-ecosystem functions like primary productivity and nutrient cycling [7]. A degraded land resource base cannot provide these agro-ecosystem services. Therefore, it is crucial to preserve the quality of the soil in order for it to sustainably carry out its production and environmental-related tasks [8]. For sustained productivity, the maintenance of soil fertility on a long-term basis is a prerequisite. For sustained soil fertility, it is essential that organic matter and nutrients removed in harvest or produce plus those lost through physical, chemical and biological processes are compensated through external addition on a regular basis such that organic matter status is maintained and nutrient balances are not negative in the longer term. Moreover, the maintenance of soil organic matter level at a threshold level, which depends on the soil type and climatic factors, is of critical importance for maintaining the physical, chemical and biological integrity of the soil, and to perform its agricultural productivity and environmental functions on a sustainable basis [9]. Two main categories can be used to group the detrimental impacts on soil quality that result in soil deterioration. One adverse consequence is soil erosion brought on by wind and water [10]. The degradation of the soil's physical, chemical, and biological characteristics causes the second adverse effect [11]. The soil resource in agricultural ecosystems offers vital functions that primary production sectors depend on and need to be managed [12]. Finding a tillage strategy that is both environmentally benign and sustainable in terms of crop output is necessary due to the increased concern for food security brought about by better soil management practices [13]. Due to the rising global population, there is a growing concern that human demographics could surpass sustainable levels. This presents a significant obstacle in ensuring an ample supply of food, fodder, and agricultural goods, particularly in less developed nations [14]. Discovering alternative and sustainable methods to fulfill the increasing food requirements while also preserving biodiversity poses a significant hurdle for mankind. The promise of utilizing agricultural regions abundant in biodiversity and fertile soils to promote sustainable food manufacturing presents notable productivity, as well as environmental and social benefits that surpass those offered by industrial farming [5]. Among the various soil organisms, bacteria play an active role in breaking down organic matter, releasing essential chemical nutrients that promote the growth of plants. The populations of microorganisms differ within and across distinct soil types and environments, with bacteria being the most abundant.

Soil microorganisms play a crucial role in the carbon and nitrogen cycles within animals (including humans), plants, agriculture, and the global food web [15]. In order to achieve their primary objective of survival through reproduction, soil microorganisms essentially transport carbon between environmental compartments. As a result, microorganisms use a variety of organic and inorganic carbon forms as sources of energy and carbon [16]. The warming of the climate will induce alterations in soil temperature, moisture levels, pH, and other environmental aspects of soil. These changes can have direct or indirect impacts on the makeup of microorganism communities, their physiological development, and their ecological function in the soil [17]. Elevated soil temperatures will heighten the activity of soil microorganisms and enzymes, hastening the breakdown and absorption of organic matter, intensifying microbial metabolic processes, and increasing the respiration rate of microorganisms. Consequently, this will lead to an elevated rate of decomposition for available carbon. Additionally, the temperature rise enhances the nitrogen utilization efficiency of microorganisms [18], augments the constraint of phosphorus on plant growth and microbial actions, and diminishes phosphorus utilization efficiency. Soil microbes work together with each other and with plant roots in many ways. These interactions provide a variety of essential functions that are important for maintaining the ecological balance in soil [19]. Plant-microbial interactions can be positive or negative, depending on whether they improve or reduce plant growth. Soil fertility is closely linked to the balance of microorganisms and plants. Biofertilizers can be used to improve soil microbial status by stimulating the natural soil microbiota. In open spaces around vascular plants in arid and semiarid regions, biological soil crusts—associations of soil particles with cyanobacteria, algae, fungi, lichens, or bryophytes—are a common ground cover. Primary ecological processes are greatly impacted by biological soil crusts (BSCs). Two of the most urgent issues for ecosystem functioning to deteriorate and desertification to occur in drylands are soil stability and fertility losses. As a result of shifting mineral or organic fertilizer strategies, soil quality gradually improves. It appears that fertilizer amendments have a far greater impact on soil microbial populations than do land use or season. In general, the addition of organic matter promotes both microbial biomass and the activity of several enzymes that break down matter. Enzymatic activities, in particular, are thought to be useful markers of soil quality because they regulate the proliferation of microbes and the release of nutrients for plants [20]. This can lead to increased nutrient accessibility and decomposition of organic matter [21, 22]. The study investigated the bacterial diversity of soil in different locations and seasons. The researchers found that the diversity of soil bacteria varied depending on the soil type, location, and season. This information could be used to improve agricultural productivity by helping farmers to choose the right crops for their soil type and climate [23]. The type of soil determines the composition of the microbial population, which is linked to the particle size fractions [24]. Gu et al. [24] showed that adding farmyard manure to mineral fertilizers enhanced the variety of the soil bacterial population more than using mineral fertilizers alone [25]. It is somewhat difficult to evaluate the quality of soil because of a number of factors. To keep the soil strong, a particular mix of biological and physico-chemical elements is needed. Knowing these characteristics aids in determining the health of the soil [26]. It could also be used to develop new agricultural practices that are more sustainable and less harmful to the environment. Future research is possible because it is uncertain how these disparate effects will ultimately affect soil water supplies and the water cycle.

2. Materials and Methods

2.1. The Study of Spatial Boundaries and Area

The research area is situated in the northern part of Al-Najaf Governorate and falls under the administrative jurisdiction of Al-Najaf District. Its configuration resembles that of a triangle, with its northern border adjoining Karbala Governorate, the eastern border abutting Babil Governorate, and the southern boundary adjacent to the central regions of Al-Najaf Al-Ashraf District and the Holy Kufa District. On the western side, it shares its border with Al-Anbar Governorate, as depicted in **Figure 1**.

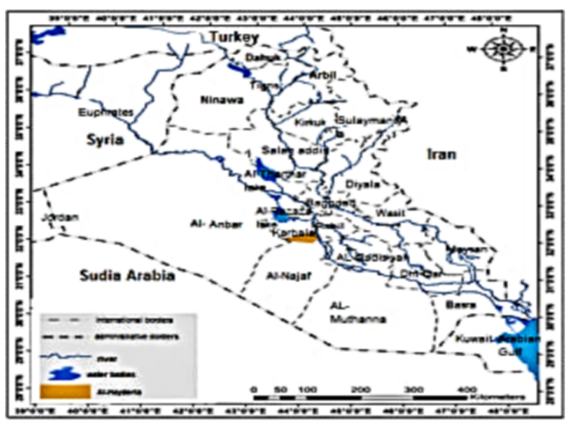

Figure 1. The geographical location of the study area of Iraq.
Source: The General Commission for Survey, Iraq Administrative Map 2007 and (Arc GIS 10.5).

Geographically, its coordinates are latitude 32°31′85 north and longitude 44°26′21 east. The combined length of its borders measures approximately 170 kilometers, with 63 kilometers shared with Karbala Governorate, 32.5 kilometers with Babil Province, 58.5 kilometers with the central district of Najaf and the Kufa district, and 16 kilometers with Anbar Province. The total area of the study zone covers 1228 square kilometers, accounting for 4.2% of Al-Najaf's total expanse. This contrasts with the province's overall area of 28824 square kilometers, as illustrated in **Figure 2**.

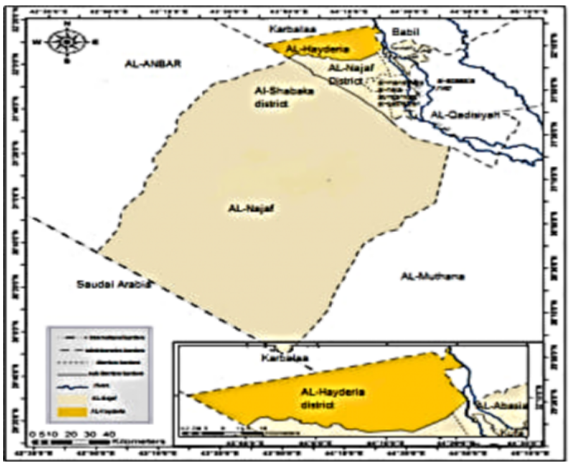

Figure 2. The administrative borders of Al-Haidara district in Al-Najaf Governorate.

Source: The General Commission for Survey, Iraq Administrative Map 2007 and (Arc GIS 10.5).

2.2. Study Site and Soil Sampling

A total of 16 samples were gathered from 16 distinct locations, chosen to represent diverse soil types within the designated study region as indicated in **Table 1**. These samples were extracted from a depth of 0–30 cm, with a distribution of (7,5,3,1) soil samples from areas characterized as overlapping, shoulders, plateau, and basins respectively. The sampling approach was deliberately randomized, factoring in both geographic coverage and land classification, encompassing cultivated and uncultivated lands across both summer and winter seasons. The samples were scraped off from encrusted environmental surface soils; after collection, samples were homogenized and stored in sterile containers at 4 °C until use in further experiments. It is analyzed in the Advanced Environment Laboratory at the College of Science, University of Kufa in Najaf Governorate to diagnose the bacterial genera and the availability of the microbial community.

2.3. Bacterial Isolates

Different types of bacteria, namely *Escherichia coli*, *Pseudomonas spp.*, and *Klebsiella spp.*, were identified and categorized from soil samples in the research area. These bacterial varieties exhibited spatial and temporal variations within the study area's soils. A series of ten decimal dilutions were performed. 0.1 mL of the second decimal dilution was added to the surface of the solid nutrient medium. The plates were incubated at a temperature between 15 to 45 degrees for 24–48 hours. Each colony was then transferred to a new plate of the same medium for the purpose of purification. These isolated colonies were maintained on agar slants at 4 °C until they were needed for further use.

Table 1. Sample locations in the study area.

Soil Site	Location and County	Sample
River shoulders	Northeast of the study area, Northern Munither lands(cultivated)	1
River shoulders	Middle east of the study area, the northern lands of Umm al-Raji (uncultivated)	2
River shoulders	Southeast of the study area, Al-Wasmiya lands (cultivated)	3
River basins	North of the center of the study area, Al- Shamtounieh, Al-Boutefijeh lands (cultivated)	4
River basins	North of the center of the study area, Al- Shamtounieh, Al-Boutefijeh (Al-Kour factories)	5
River basins	The middle of the study area, Al-Ajdaa lands near urban settlements (uncultivated)	6
River basins	The middle of the study area, Al-Majar southern, near the city center (cultivated)	7
River basins	In the middle of the study area, the southern lands of Umm Al-Raji, near Al-Ma'ani school (cultivated)	8
River basins	South of the study area, the lands of Al-Mazuka (cultivated)	9
River basins	South of the study area, Al-Majar southern lands	10
Interfering soil	South of the study area, southern Khan Hamada, Buri village (cultivated)	11
Plateau soil	North of study area, the plateau, near the sanitary landfill site (Al-Tahrir quarries) (uncultivated)	12
Plateau soil	North of the study area, plateau, tomato farms (cultivated)	13
Plateau soil	Mid plateau study area, tomato farms (cultivated)	14
Plateau soil	South of the study area, plateau, tomato farms (cultivated)	15
Plateau soil	In the middle of the study area, near the main street (Najaf-Karbalaa) column (485) (uncultivated)	16

3. Results and Discussion

Soil microorganisms are most sensitive to soil heating during a fire, especially nitrifiers, endo- and ectomycorrhizae [27]. The data presented in **Table 2** demonstrate varying spatial distribution of *E. coli* bacteria in different soil environments. In the shoulder soil, the bacterial counts ranged from 3 to 4 × 10^5 cells per milliliter in models 1 and 3, whereas no growth was observed in model 2. Similarly, the basin soil exhibited spatial variability, with *E. coli* counts ranging from 4 to 14 × 10^5 cells per milliliter in models 4, 6, 7, and 8, but no growth in models 5, 9 and 10). In the overlapping soil, *E. coli* bacteria were present at a concentration of 21 × 10^5 cells per milliliter. The plateau soil also displayed spatial variation, with E. coli counts ranging from 3 to 12 × 10^5 cells per milliliter across all samples.

Table 2. The number of *E. coli* bacteria per milliliter of soil in the study area for the month of July.

E. coli Cell ml^{-1}	Sample
3 × 10^5	1
-	2
4 × 10^5	3
6 × 10^5	4
-	5
11 × 10^5	6
14 × 10^5	7
3 × 10^5	8
-	9
-	10
21 × 10^5	11
3 × 10^5	12
4 × 10^5	13
2 × 10^5	14
3 × 10^5	15
12 × 10^5	16

Pseudomonas spp. exhibited both spatial and temporal variations in the shoulder soil. During July, their quantities ranged from 3 to 7 × 10^5 cells per milliliter, while there was no bacterial presence recorded in January for the shoulder soil samples. In the case of soil ponds, as indicated by **Table 3**, the *Pseudomonas spp.* counts ranged from 3 to 14 × 10^5 cells per milliliter in July. However, in certain samples (5 and 9), no bacterial activity was detected. In January, the counts were between 2 and 8 × 10^5 cells per milliliter, and again no activity was observed in samples 5, 8, 9, and 10. The "overlapping" soil exhibited a bacterial count of 19 × 10^5 cells per milliliter in July, which was like the count of 10 × 10^5 cells per milliliter in January. The number of bacteria in **Table 3** varied both spatially and temporally. In July, the number of bacteria ranged from 3 to 7 × 10^5 cells ml^{-1}, while in January, the number of bacteria ranged from 2 to 3 × 10^5 cells ml^{-1}. No bacterial activity was recorded in model 12 in both months.

Table 3. The number of bacteria (*P. spp*. cell ml^{-1}) in the soil of the study area for the months of July and January.

Spp. January P	Spp. July P.	Sample
-	3 × 10^5	1
-	7 × 10^5	2
-	7 × 10^5	3
3 × 10^5	9 × 10^5	4
-	-	5
19 × 10^5	12 × 10^5	6
15 × 10^5	14 × 10^5	7
-	3 × 10^5	8
-	-	9
-	3 × 10^5	10
10 × 10^5	19 × 10^5	11
-	3 × 10^5	12
3 × 10^5	7 × 10^5	13
3 × 10^5	4 × 10^5	14
2 × 10^5	6 × 10^5	15
3 × 10^5	5 × 10^5	16

The number of *Klebsiella* bacteria in the soil of the shoulders varied from 2 × 10^5 cells ml^{-1}. In models 1 and 3, the number of bacteria was 2 × 10^5 cells ml^{-1}, but there was no growth in model 2. The number of bacteria in the soil of the ponds also varied spatially, ranging from 2 cells ml^{-1} to 8 × 10^5 cells ml^{-1}. The highest number of bacteria was found in the interfering soil, where the number was 14 × 10^5 cells ml^{-1}. The number of bacteria in all samples ranged from 3 cells ml^{-1} to 8 × 10^5 cells ml^{-1}. Regarding the *Klebsiella* bacteria outlined in **Table 4**, their distribution in the soil of the shoulders exhibited spatial variations. Specifically, their quantities were measured at 2 × 10^5 cells per 1 ml in models 1 and 3, while no growth was observed in model 2. In the context of soil from the ponds, the spatial distribution of these bacteria also showed variability, with levels ranging from 2 to 8 × 10^5 cells per 1 ml across all samples. Notably, the soil from the intervening areas recorded a count of 14 × 10^5 cells per 1 ml of *Klebsiella* bacteria. Their population in the soil of all samples fluctuated between 3 to 8 × 10^5 cells per 1 ml.

Evidently, bacteria exhibit activity influenced by specific environmental circumstances. It was noted that the functionality of certain bacterial strains waned during colder seasons, only to be reactivated in warmer periods. This phenomenon stems from various factors conducive to their growth and propagation, including temperature, moisture levels, and the distinct soil composition found within the surveyed regions.

Table 4. The number of *Klebsiella* bacteria found in the soil of the study area in July, measured in cells per milliliter.

Klebsiella **Cell ml^{-1}**	**Sample**
2×10^5	1
-	2
2×10^5	3
3×10^5	4
2×10^5	5
9×10^5	6
8×10^5	7
3×10^5	8
3×10^5	9
3×10^5	10
14×10^5	11
8×10^5	12
5×10^5	13
3×10^5	14
5×10^5	15
7×10^5	16

Soil plays an important role in providing water, nutrients, and an adequate environment for plant growth. It is responsible for the maintenance of biodiversity, crop yield, water partition, solute flow, filtering, and buffering, as well as nutrient cycling [28]. As anthropogenic activities increase, plants growing on heavy metal-polluted soil see a decline in growth, performance, and yield as agricultural plants. These effects, which are more noticeable when the metal is more toxic and more accessible to plants, are the result of physiological alterations and biochemical reactions brought on by the presence of poisonous metal ions. The availability of metals in soil is influenced in a number of ways by soil characteristics, particularly pH. Furthermore, some physical characteristics of the soil, such as its density, moisture content, ability to retain water, charge of soil colloids, complexation with ligands, and specific surface area, might change the toxicity of certain heavy metals in plants as well as their bioavailability [29]. Through their roots, which also help to increase the stability of soil aggregates and consolidate their matrix, plants play a beneficial role in the interaction between water and soil in terms of fertility, biodiversity conservation, the presence of microorganisms, and the thermal and hydric regime. From the surface, they model the environment and soil development. Additionally, the physical action of the plant roots increases the rhizosphere's chemical and biological activity by creating preferential flow channels around the roots [30]. *Escherichia coli* and other indicator bacteria were once believed to be found exclusively in the digestive tracts of warm-blooded animals, including humans [31]. E. coli has been employed as a marker of fecal contamination in food and water, suggesting the potential presence of fecal pathogens including Shigella and Salmonella [32]. In the overlapping soil, *E. coli* bacteria were present at a concentration of 21×10^5 cells per milliliter. The favorable climate and appropriate soil conditions create an environment conducive to the development of a thriving microbial community. This is what the researchers focus on they have directed their attention globally towards different aspects of the soil , that profoundly impact plant growth. One noteworthy discovery is that soil moisture content closely emulates vital soil attributes like texture, organic matter concentration, and macroporosity. This moisture content plays a direct and pivotal role in governing factors such as the vegetation type present, its density, and the overall consistency of its distribution [33].

The number of *P. spp.* bacteria per milliliter of soil in the study area for the months of July and January. The number of bacteria was increasing, while in January the number of bacteria was decreasing Therefore, soils abundant in a diverse microbial population are productive and contain ample organic material that enhances plant growth. This is the concept to which he alluded [17, 34]. The warming of the climate will lead to shifts in soil conditions such as temperature, moisture levels, pH, and other environmental factors within the soil. These changes can have both direct and indirect impacts on the makeup of the microbial community, the growth patterns of microorganisms, and the overall ecological role they play. Elevated soil temperatures will spur greater activity among microorganisms and soil enzymes, hastening the breakdown and absorption of organic substances. This heightened microbial metabolic process will consequently amplify the respiration rate of microorganisms, culminating in a swifter breakdown of accessible carbon sources. Moreover, the temperature elevation enhances the efficiency of nitrogen utilization by microorganisms, while it also intensifies the constraints of phosphorus availability on both plant growth and microbial functions, leading to a dampening effect on phosphorus utilization .

The bacterial activity was high in models 7–11, which are located near residential areas and Husseinian processions. This is because these processions are located along the road that separates the plateau soil from the basin soil. The basin soil is sloping, meaning that it descends from the plateau towards the Euphrates River. This sloping land likely provides more moisture and organic matter, which are essential for bacterial activity This accounts for the elevated levels of bacterial proliferation in these regions, In contrast to the study areas, the microbial communities were affected by climate.

Climate change can affect soil microbes in two ways: directly, through changes in temperature, moisture, and other environmental factors; and indirectly, through changes in the availability of food and nutrients. These changes can alter the composition and activity of soil microbial communities, which can have a significant impact on the soil's ability to store carbon and other nutrients [35]. The health of the soil is a subset of the health of the ecosystem. Characteristics of a healthy ecosystem include stability, resilience to stress or disruption, and the integrity of energy and nutrient cycles.

4. Conclusions

Soil health is largely an ecological trait, but soil quality also includes physical and chemical qualities in addition to biological ones. The stability and resilience of an ecosystem in the face of stress or disturbance have been used to characterize its health. Therefore, we propose that monitoring the soil microbial community's reactions to the application of diverse stress stimuli at varying intensities could yield indications for soil health. Measures of soil health could include the magnitude of a response and the amount of time it takes to return to its pre-stress state.

Agricultural systems are tasked with the responsibility of generating food. The absence of any commercial or financial engagements could potentially be seen as a conflict of interest. Managing stress and non-management of agricultural soils involves the pursuit of fertile soils abundant in microbial communities. The eradication of pests and pathogens leads to a rise in harvest and a reduction in substantial crop losses annually. The pressures arising from shifting climatic conditions pose a challenge to global crop production. Approaches to curbing losses in crop production and disease control need to be adopted. This underscores the significance of seeking fertile lands and bringing them together for sustainable agriculture. This effort not only enhances the treatment of healthy plants but also boosts yield, productivity, soil health, and shields against environmental stress.

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Data Availability Statement

Data unavailable due to privacy restrictions.

Conflicts of Interest

The authors declare no conflict of interest.

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