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Assessment of soil microbial properties in some regions affected by climate change

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ABSTRACT

Climate change and human activity may have profound impacts on ecosystems sustainability and soil degradation. Within this context, soil microbial properties represented by microbial biomass and enzymatic activities have been used as soil quality assessing bioindicators. Twenty soil samples were collected from five unmanaged lands with native vegetation cover in areas around Baghdad, Iraq. The microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) were evaluated by the chloroform fumigation - extraction method. The soil enzymes activity was estimated by fluorescence enzyme assays. The current study showed a significant decrease in the activity of soil microbial communities in this region in response to climate changes that affected physicochemical soil properties. Neither pH nor electrical conductivity was significantly correlated with phosphatase activity. Electrical conductivity was negatively correlated with microbial biomass content and nitrifying enzymes activity. Soil moisture was strongly correlated with microbial biomass and enzymatic activity. Furthermore, microbial biomass carbon and nitrogen were significantly lower at all study sites. Our data indicate that the soil state was stressful, specific, and less efficient in supporting soil microbial activity. Consequently, lands reclamation would contribute to reducing soil degradation. This is the first analysis of bioindicator measurements of soil in a hot and dry ecosystem in the Middle East.

Keywords: Soil microbial properties, Microbial biomass, Lands management, Climate change.
Article type: Research Article.

INTRODUCTION

Soil is the environment where take place all necessary natural activities of life and that are highly dependent on the activity of the soil microbiome (Amaral *et al.* 2012; Wienhold *et al.* 2014; Zinchenko *et al.* 2021; AL-Lami & Al-Mayaly 2022). Microbial soil enzymes play a key role in many chemical reactions and ecosystem functions (Nkongolo & NarendrulaKotha 2020), such as fixing nitrogen, dissolving phosphorous, nutrient cycling, and decomposition (Pii *et al.* 2015; Andreote & E Silva 2017; Vega Ávila *et al.* 2018). Due to its most sensitivity to environmental and climatic changes and human activities (Amaral *et al.* 2012; Wienhold *et al.* 2014), soil microbial characteristics such as an abundance of microbial communities, microbial biomass, enzymatic activities, and nitrification are often used as biomarkers to assess soil quality and fertility (Schloter *et al.* 2017). Most of the previous studies on soil microbial properties focused on agricultural systems, forests, and pastures (Wienhold *et al.* 2014; Huera Lucero *et al.* 2020; Utobo & Tewari 2020). These studies showed a negative impact of the converting processes forests on agricultural lands or pastures. Tillage, crop management, use of herbicides and agrochemicals all lead to significant changes in soil microbial communities (Vega-Ávila *et al.* 2018). Ramesh *et al.* (2019) mentioned that intensive cultivation and fertilizers significantly reduce microbial biomass carbon. Our knowledge of microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) tells us about the health of the soil (Ramesh *et al.* 2019), since it is very responsive to the changes that occur in the soil (Juan *et al.* 2008). Many factors affect the microbial activity of the soil such as temperature, acidity, moisture content, type of vegetation cover, organic matter, nutrients, and management (Bloem & Breure 2003; Cruz *et al.* 2019; Huera

Lucero *et al.* 2020). Soil microorganisms produce many extracellular enzymes that help in obtaining nutrients and energy (Scotti *et al.* 2015). The levels of enzymes in the soil depend on the number of microorganisms present, the substrate concentration, and the environmental conditions (Utobo & Tewari 2015; Huera Lucero *et al.* 2020). Soil enzymes are useful bio-indicators for measuring soil quality, due to their relationship to soil biochemical processes (Van Kessel *et al.* 2015). Several key enzymes involved in the transformations of carbon, nitrogen, phosphorous, and sulphur have been described, which are an indication of the proper functioning of the soil and its functions (Bossio *et al.* 2006; Nannipieri *et al.* 2012). Nitrification is a crucial step in the nitrogen cycle. Ammonia and nitrite-oxidizing bacterial groups act on the availability of N as a plant nutrient (Pereira E Silva *et al.* 2012). Nitrification rates affect vegetation type and environmental conditions (Utobo & Tewari 2015). Yao *et al.* (2011), indicated that microbial activity in tropical soils is higher than in temperate climates. Margalef *et al.* (2017), pointed out that the availability of nutrients in the soil and the effects of climate are among the most important factors that affect the activity of the phosphatase enzyme. Land management is also one of the most important factors affecting the microbial activity and organic matter in the soil (Vega Ávila *et al.* 2018). Human activities often hurt the health and balance of the soil. Therefore, knowing what is happening in the soil is of paramount importance to maintain soil quality and productivity (Jacoby *et al.* 2017). Few studies have been conducted on the properties of microbial soils in the Middle East (hot environments). Iraq suffers from a continuous deterioration in the ecosystem due to human activity and climate changes. Therefore, the objectives of the current study were (1) to assess the microbial properties of soil in Iraq and (2) to determine the effect of some environmental factors.

MATERIALS AND METHODS

Study area

The study was carried out in Baghdad, Iraq, catalogued in the Middle East as a hot climatic region. The climate is characterized by mean annual temperature and rainfall of 22.9 ºC and 120 mm, respectively (Salman *et al.* 2017). Maximum and minimum temperatures during the summer are 28 ºC and 50 ºC, respectively. *Suaeda aegyptica*, *Alhagi maurorum*, *Salsola longifolia*, and *Haloxylon articulatum* were the main plants in the region, all of them are classified as perennial halophytes (Mehrabian *et al.* 2009).

Soil sampling

Sampling was carried out between May and June 2020. Five different plots of land with native vegetation cover were studied. At each plot, four main sampling points (at a minimum distance of 100 m between each sample), a composite sample was made from three sub-samples. The samples were treated and passed through a sieve with mesh size of 2-mm and stored in plastic bags, then refrigerated at 4 °C and transported to the laboratory until further analyses.

Soil physicochemical Analysis

The physicochemical parameters measured were soil water content, pH, and electrical conductivity (EC). To measure the soil moisture, the Soil-Clik TM equipment with SC-PROBE sensor was used. To determine the pH, the potentiometer in water was used. The electrical conductivity (EC) was determined by EC-probe adapted to a WET sensor.

Analysis of soil quality Bio-indicators

The chloroform fumigation - extraction method was used to determine the microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) as described by Vance *et al.* (Vance *et al.* 1987).

Measurement of soil enzymatic activities

The soil enzymes activity was measured by the fluorescence enzyme assays. Protocol assay setup, incubation of assay plates, and fluorescent measurements on a microplate fluorimeter were described by (Bell *et al*. 2013) The statistical analysis (ANOVA) was used to identify significant changes in parameters among all study plots. All experiments were carried out in triplicate.

RESULTS

When analysing the soil physicochemical properties, significant differences were found for the electrical conductivity (EC; $P < 0.01$) between the samples, where it was within range of 1.2 - 5.6 dS m^{-1}. The moisture and pH soil were 6.2 - 11.4 % and 6.9 - 7.7, respectively. Also, direct correlations were found between electrical conductivity and soil moisture (Table 1; Fig. 1). In all soil samples, MBC and MBN contents ranged from 281.3

to 461.8 mg kg^{-1} and 8.5 to 13.2 mg kg^{-1} respectively, with significant ($p < 0.01$) differences between soil samples (Fig. 1). The highest microbial biomass content was 461 mg kg^{-1} at pH 7.1, electrical conductivity 1.3, and soil moisture content of 11.4 at plot 2, while the lowest was 252 mg kg^{-1} at pH 7.6, electrical conductivity 5.6, and soil moisture content of 6.3 at Plot 4. Plot 2 was characterized by having the highest contents of MBC/MBN (Fig. 1). In the case of the enzymatic activity, there were significant differences between the soils. The nitrifying enzymes were higher in all soil samples compared to phosphatase (Fig. 2). Although the values of the variables were different in this study, the phosphatase activity did not differ significantly between soil samples. Also, we found that phosphatase activity was less than half that of nitrifying enzymes in soil, and this was consistent across all the samples. Plot 2 exhibited the highest enzymatic activity, which may be due to the elevated water content and microbial biomass, while the declined soil salinity (Table 1). So that, a positive correlation was found between microbial biomass and enzymatic activity. In this study, the plant type did not significantly affect the microbial biomass and enzymatic activity in all study sites, so that, all of them were halophile plants. The pH did not significantly contribute to affecting microbial biomass and enzymatic activity. In turn, Soil moisture was strongly correlated with microbial biomass and enzymatic activity (Table 1, Figs. 1-2). The results exhibited the negative role of electrical conductivity in affecting the nitrifying enzyme activities and microbial biomass, while the effect was less on phosphatase activity (Fig. 2).

Table 1. SM: soil moisture; pH: acidity coefficient; EC: electrical conductivity; MBC: microbial biomass carbon; MBN: microbial biomass nitrogen; NEA: nitrifying enzymes activity. PHA: phosphatase activity.

Variables	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
SM (%)	7.5 ± 0.4	11.0 ± 0.4	8.7 ± 0.8	6.6 ± 0.4	9.4 ± 1
pH	7.2 ± 0.2	7.1 ± 0.1	7.4 ± 0.2	7.5 ± 0.2	7.0 ± 0.1
EC (dSm-1)	1.9 ± 0.2	1.3 ± 0.1	4.2 ± 0.5	5.0 ± 0.6	2.3 ± 0.2
MBC (mg kg^{-1})	340.3 ± 25	441.6 ± 28	314.7 ± 31	269.2 ± 32	363 ± 43
MBN (mg kg^{-1})	12.5 ± 1.6	13.6 ± 0.4	9.4 ± 1.5	8.1 ± 0.4	11.6 ± 0.3
MBC/MBN	19.2 ± 0.3	20.5 ± 0.5	17.7 ± 0.2	16.3 ± 0.4	18.6 ± 0.2
NEA (µmol g^{-1} h^{-1})	1.83 ± 0.13	2.25 ± 0.11	1.38 ± 0.18	1.12 ± 0.11	1.31 ± 0.10
PA (µmol g^{-1} h^{-1})	0.88 ± 0.04	0.89 ± 0.03	0.66 ± 0.06	0.71 ± 0.02	0.77 ± 0.05

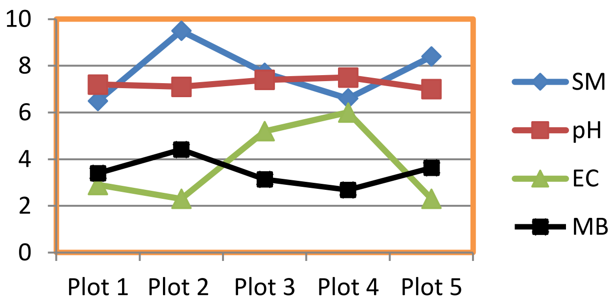

Fig. 1. Relationship between soil moisture, pH, electrical conductivity, and microbial biomass in Baghdad soil, Iraq (2021).

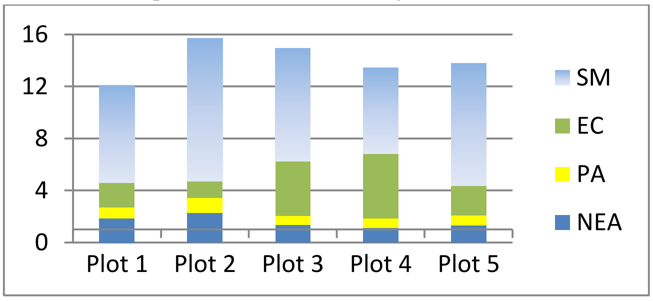

Fig. 2. Relationship between soil moisture, electrical conductivity, and enzymes activity in Baghdad soil, Iraq (2021).

DISCUSSION

There was a significant correlation between microbial biomass and enzyme activities on the one hand and soil properties on the other. The present results show the characteristics of the soil that experienced severe local climatic conditions such as high salinity, temperature, lack of nutrients, vegetation cover, and drought. Salman *et al.* [22] reported significant increases in temperature in all Iraq higher than any other regions in the world, where the temperature can increase 1 °C/decade. These changes increased the drought and decreased nutrients and vegetation, ultimately directly contributing to soil degradation. The COP26 UN Climate (Conference 2021) classified Iraq as one of the five most affected countries in the world by climate change. In this study, the results indicate that physicochemical soil properties were negatively affected by climatic conditions and human activity in this area. These characteristics apply to arid and semi-arid environments. Vega-Ávila *et al.* (2018) indicated that arid environments display low contents of organic matter, moisture, and vegetation, as well as high salinity. Rietz & Haynes (2003) also indicated that there is a negative significant relationship between soil salinity and microbial biomass. Although in the present study there was no significant relationship between pH and microbial biomass, it is an important factor especially in humid soils, which is a critical factor to microbial activity (Tian *et al.* 2017). Touhami *et al.* (2020) found that plant species directly affect microbial biomass in soil. In the current study, it appears that halophytes are less closely related to soil microbes than other plants. One of the main factors to assess changes in soil properties is microbial biomass. Correlation analysis showed that MBC and MBN contents were significantly correlated with the physicochemical parameters of soil. According to the results, the highest concentrations of MBC and MBN belonged to Plot 2, while lowest was found in Plot 4 (Table 1). It is possibly caused by the soil restoration of some positive properties as water availability and low salinity. Cruz *et al*. (2019) reported that the high content of MBC is positively associated with soil health properties. (Rietz & Haynes 2003) also indicated that there is a negative significant relationship between soil salinity and microbial biomass, in contrast to the water availability, which is a driving factor for the upraised microbial activity (Margalef *et al.* 2017). Compared to the current study, higher concentrations of microbial biomass were reported in tropical forests, croplands, and pastures (Cordero *et al.* 2019; Huera Lucero *et al.* 2020). However, this small amount of microbial mass is very important and can serve as an indicator of soil restoration potential. Cruz *et al*. (2019) reported that a very small amount of MBC in the soil is a guide of carbon immobilization. In addition, MBC and MBN reflect the microbial abundance and soil health status, so that, they act as the living nutrient in the soil (Li *et al.* 2018). Although numerous studies were performed on nitrification rates in agricultural, herbaceous, and forest soils (Yao *et al.* 2011; Pajares & Bohannan 2016), our knowledge about these processes in soils with hot and dry climates is very little. Nitrification is a process sensitive to environmental changes, so it is often used as an indicator of soil quality (Pereira E Silva *et al.* 2012; Scotti *et al.* 2015). In this study, a significant decline in the nitrification rates was found compared to other environments, whether in agricultural fields (Wienhold *et al.* 2004; Pereira E Silva *et al.* 2012), grassland (Cordero *et al.* 2019) or forest soils (Xue *et al.* 2006; Pajares & Bohannan 2016). On the other hand, Phosphatase was estimated that represent potential P cycling activities. Phosphatase plays a fundamental role in the transformation of P in soil organic matters into available forms (Margalef *et al.* 2017). The current results showed a significant decrease in the activity of this enzyme compared to cropland (Vega-Ávila *et al.* 2018) and forest soil (Cabugao *et al.* 2017), exhibiting that a phosphatase activity was negatively affected in this ecosystem. Margalef *et al.* (2017) found that phosphatase activity is mainly related to climatic regions and nutrient availability. Phosphatase activity was lower than the nitrifying enzyme activities in this study, which may be due to the decline in the demand for phosphorous by plants as a result of drought. Furthermore, Margalef *et al.* (2017) suggested an increase in phosphatase activity in soils with a good content of organic matter and vegetation. Many authors have suggested that land management has a negative impact on the stability and activity of soil microbial communities (Shi *et al*. 2008; Huera Lucero *et al.* 2020). Land-use change usually hurts nutrient-cycling processes (Pajares & Bohannan 2016). However, the microbial activity in this study was low despite the land being unmanaged. This result indicates that soil microbial communities can be affected by other factors regardless of how the land is used. Converting semi-arid lands in Iraq to agricultural lands would contribute to reducing soil degradation. Xue *et al.* (2006) also indicated that reclamation of wasteland greatly helped in increasing microbial biomass and enzymatic activity. In this study, potential of the microbial biomass and enzymatic activity trended lower in all sites compared to the previous studies. Also, that soil microbiome activity was significantly correlated with soil physical-chemical variables and not only with land management, while the negative impact of global climate changes was significant on the activity of microbial communities in Iraq.

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