COMPARISON OF MICROBIAL ACTIVITIES OF WETLANDS AREAS TO SOME SOIL CHARACTERISTICS

Ahu Alev Abaci-Bayar[1,*], Kadir Yilmaz[2]

[1]Soil Science and Plant Nutrition Department, Kirsehir Ahi Evran University, Agricultural Faculty, Kirsehir, 40200, Turkey
[2]Soil Science and Plant Nutrition Department, Kahramanmaras Sutcu Imam University, Agricultural Faculty, Kahramanmaras, 46100, Turkey,

ABSTRACT

The Eastern Mediterranean Region is described as the richest region in terms of wetlands and in this study aimed to examined the microbiological characteristics of the wetland lands of Amik, Gavur and Golbasi Lakes in Eastern Mediterranean Region. The relationships between total microorganism counts and some soil characteristics of 3 different wetland lands in the Eastern Mediterranean region have been determined. As a result of the biological analyzes carried out on three different wetland soils; the highest number of total actinomycetes were found from microorganisms in the field soils, this is followed by the moment of total algae, total bacteria and the total fungi. It was first observed that microbial activity in the soil of Amik Lake, where the most degradation was caused by drying, decreased. In the same area, the total amount of fungi, bacteria, algae and actinomycetes was found to be the lowest in this study. It has been found that the total amount of fungi, bacteria and actinomycetes in the soil of Gavur Lake, which has been degraded to moderate level, is the highest value. It has been observed that the total amount of algae is the highest in the Golbasi Lakes, which is still partially preserving its wetland characteristics. As a result, it has been determined that all microorganism groups in the Gavur and Golbasi Lake areas are considerably higher than Amik Lake soil, which has undergone decaying, based on the lands in the lake. There were statistical relations between total fungi with the soil organic matter (r= 0.432**), percent saturation (r= 0.555***), soil reaction (r= -0.526***), plastic limit (r= 0.413**) and liquid limit (r= 0.414**) values. There was a positive relationship between total algae with organic matter (r= 0.541***), and negative relations with soil reaction (r= -0.484***). It was determined that there was a positive correlation between the total actinomycet and the plastic limit and the liquid limit (r= 0.437**, r= 0.362*), which is negative between bulk weight and hydraulic conductivity (r= -0.360*, r= -0.381**).

KEYWORDS:
Wetland, Soil, Microorganism, Degradation, Drought

INTRODUCTION

Wetlands can be distinguished by three main criteria: hydrology, physico-chemical environment and biodiversity. They are natural areas, where biological diversity is the richest, with the functions and values that cannot be compared with any other ecosystem on earth. Soil, in addition to its physical and chemical functions, has a complex biological structure [1]. Microorganisms that provide biological activity in the soil provide soil fertility in various forms [2]. It is known that the major groups of microorganisms are bacteria, algae, fungus and actinomycetes [3]. The plant and organic layer on the soil are both a source of nutrients and shelter for fungi. All soil microorganisms are critically important in the preservation of soil functions, with their roles in key ecosystem processes such as decomposition of organic material; removal of toxic substances; carbon, nitrogen, phosphorus and sulfur cycles and formation of soil structure in natural soils and tillages [4]. The wetland ecosystem is characterized by hydric soils that support hydrophilic vegetation. Hydrology is known as a dominant factor that controls microbial processes in wetlands [5-6-7]. High water level increases the rate of the anaerobic functions such as denitrification, methane genesis and, amount of sulphate reducing [8]. And the aerobic function such as nitrification decreases this rate [9].

In a study in Amik, Gavur and Golbasi Lakes, the chemical properties of the field soils were investigated; and the higher level of degradation and mineral decomposition in Amik Lake soils is explained by the higher pH value of the plain soil and the relative increase in the amount of calcium carbonate in the soil [10]. The soil reaction is important for plant growth; and it has been noted that, pH has a great effect on the plant's uptake of nutrients, the solubility of toxic ions in water and the activity of microorganisms [11]. Many studies have indicated that; microbial activity should naturally increase as the level of organic material increases; and the microorganism activity and especially the number of fungi raise in environments where soil pH is low [12-15]. The decomposition of soil organic matter is proportional to the functions of all microorganisms in the soil.

The purpose of this study is; determine the total microorganism population in wetland soils of Gavur, Amik and Golbasi Lakes, which are located in the Eastern Mediterranean Region. The statistics of the total numbers of microorganisms among the three areas were examined by making comparisons.

MATERIALS AND METHODS

Working area. Amik, Gavur and Golbasi Lakes, located in Eastern Mediterranean Region, are considered as important wetlands of Turkey (Figure 1). Amik Lake, which is the first research area, is located within the boundaries of the Hatay province of the Mediterranean Region. Gavur Lake, which is chosen as the second research area, is located in the Antakya-Kahramanmaras graben and with an average altitude of 478 m above sea level. The third research area was Golbasi Lakes in Adiyaman province. The Golbasi Lakes (Inekli, Azapli and Golbasi Lake), which form the most important wetland between the Mediterranean Region and the Southeastern Anatolia Region, are located in the Golbasi Depression within the Eastern Anatolian Fault Zone. Soil specimens were taken from the soil profiles opened with a cross section from the lake open-water zone of Amik, Gavur and Golbasi Lakes, according to the horizon basis. For microbiological analysis, 48 soil samples were used as material in this study.

Methods. The total number of microorganisms in the soil samples taken was determined in accordance with the principles reported by Jackson [16], Potato Dextrose Agar (PDA) medium for determining the total number of fungi; Plate Count Agar (PCA) medium for determining the total number of bacteria; algae medium for determining the total number of algae, and starch-casein medium for determining the total actinomycetes were created according to methods reported by Kiziloglu and Bilen [17]. Percentage of saturation with water was analyzed according to Demiralay (1993) [18], soil reaction analysis by Thomas [19], electrical conductivity by Tüzüner [20], organic matter analysis by Nelson and Sommers [21], available phoshorus analysis by Olsen et al. [22] reported by Kuo [23], bulk density analysis reported by Demiralay (1993) [18], aggregate stability analysis by Kemper and Koch [24], plastic limit and liguid limit analysis by Sayin [25]. Variance analysis was performed by using SPSS program (IBM SPSS Advanced Statistics version 19.0.0) with the data obtained from the biological analyses on all 48 soil samples taken from Amik, Gavur and Golbasi Lakes wetlands. As a result of the variance analysis performed on both the field soils and the soil contained in the lake open-water zone, the differences between the groups that were found to be significant were examined by Duncan's multiple comparison tests. In addition, a logarithmic transformation has been applied to the data to provide the assumptions of the variance analysis.

RESULTS AND DISCUSSION

The results of the biological analysis performed on three different areas are given in Table 1. When Table 1 was examined, the maximum average number of fungi was found in Gavur Lake soil with $3.97*10^5$ cfu g^{-1}, followed by Golbasi Lakes and Amik Lake respectively. The total number of bacteria was found to be the highest in Gavur Lake and the lowest in Amik Lake. The total number of algae was highest in Golbasi Lakes and the lowest in Amik Lake, and the total number of actinomycetes was found to be highest in the Gavur Lake and the least at Amik Lake. It was observed that the lowest total fungi, bacteria, algae and actinomycetes were found in the soil of Amik Lake, while the highest number of total fungi, bacteria and actinomycetes were found in Gavur Lake and the highest number of algae was found in Golbasi Lakes.

FIGURE 1
Satellite view of work areas

TABLE 1
Total number of soil microorganisms

Horizon	Fungi	Bacteria	Algae	Actinomycete
	cfu g^{-1}	cfu g^{-1}	cfu g^{-1}	cfu g^{-1}
		Amik Lake		
Minimum	$1.10*10^3$	$7.30*10^4$	$1.30*10^3$	$5.00*10^3$
Maximum	$6.00*10^5$	$1.09*10^6$	$2.40*10^5$	$4.05*10^6$
Average	$9.47*10^4$	$2.76*10^5$	$7.18*10^4$	$1.05*10^6$
		Gavur Lake		
Minimum	$4.00*10^3$	$2.90*10^4$	$2.00*10^3$	$4.20*10^4$
Maximum	$1.20*10^6$	$8.42*10^6$	$7.04*10^6$	$2.17*10^7$
Average	$3.97*10^5$	$1.34*10^6$	$1.19*10^6$	$3.26*10^6$
		Golbasi Lakes		
Minimum	$1.30*10^3$	$9.30*10^3$	$1.25*10^4$	$2.63*10^4$
Maximum	$2.50*10^6$	$8.40*10^6$	$1.39*10^7$	$1.53*10^7$
Average	$3.60*10^5$	$1.20*10^6$	$1.80*10^6$	$3.03*10^6$

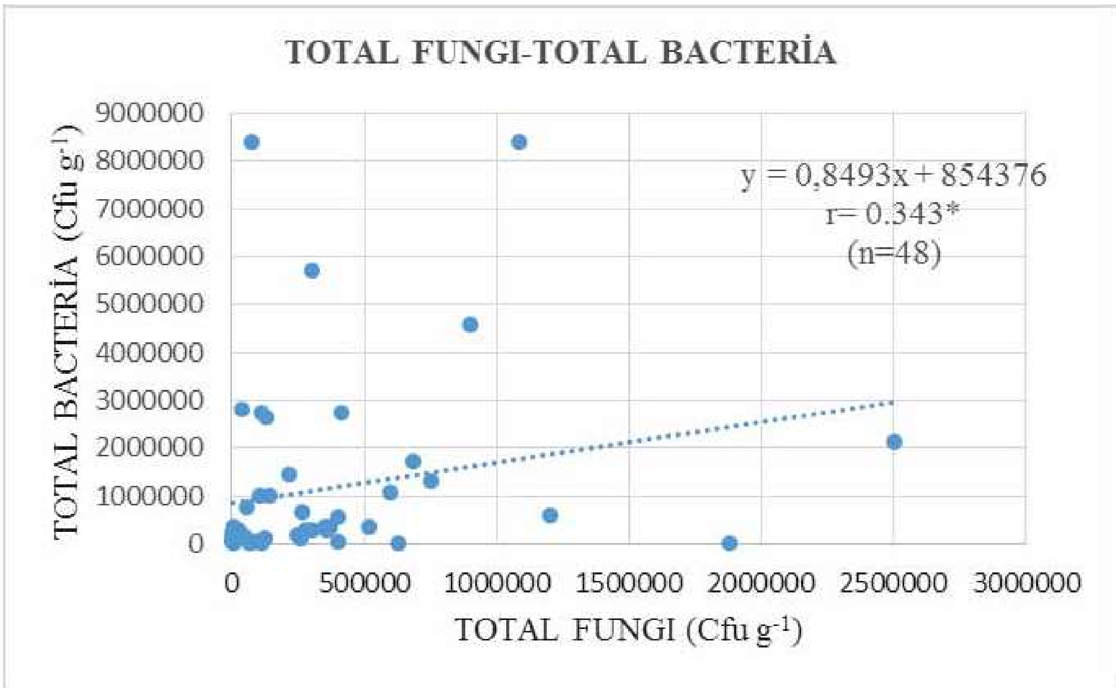

FIGURE 2
Relationship between total fungi and total bacteria

As a result of the correlation analysis, it was determined that there is a significant positive correlation ($p<0.5$) between the total number of fungi in the soil and the total number of bacteria (Figure 2). Similar findings have been reported by He et al. [26], where researchers have studied the soil under different vegetation. They reported that there was a strong positive correlation between total bacteria and total fungus counts by performing Pearson correlation analysis. The most important role of bacteria and fungi in the soil is to provide soil ventilation. It was determined that there was a significant positive correlation ($p<0.01$, $p<0.01$) between the total number of fungi and the total number of algae and the total number of actinomycetes. These findings support that the optimal living conditions for fungi and actinomycetes are similar. Huang et al. [27], have identified 3 wetlands in China's Chongqing city as pilot; and they have studied soil microorganisms and enzyme activities. They pointed out that there was a positive correlation between the total number of fungi in the soil and total actinomycete at the $p<0.01$ significance level. Egambardiyeva [28] investigated the microbial population activity in the soil of the Chatkal biosphere reserve. For this, 5 different soils (typical sierozem soil, dark sierozem soil, brown carbonated soil, typical brown soil, decomposed brown soil) were identified; and it was concluded that the least microbial activity was in sierozem soil and the most activity was in brown carbonated soil. İt has been reported that there is a similar increase in total actinomycetes and fungus amounts, especially in brown carbonated soil.

As a result of the correlation analysis between the total number of fungi in the soil and the saturation percentage value, soil organic matter and available phosphorus value; it is found that there is a significant positive ($p<0.01$, $p<0.1$, $p<0.5$) relationship. Since soil organisms play an important role in the decomposition of organic residues that fall on the soil, the diminution or disappearance of these creatures causes the organic waste falling to the soil to remain and accumulate for a long time without decomposing. Decreasing or stopping of the decomposition also slows down the supply of mineral nutrients required for plants [29]. As reported by Abaci Bayar [10], the amount of organic matter (1.23%) of Amik Lake soils, which are dried and subjected to the most soil degradation, is much lower than the amount of organic matter (11.42%) of Gavur Lake soils. In this case, it can be stated that the total microbial activity in Gavur Lake is higher than the microbial activity in the soil of Amik Lake. It was found by the same researcher that the value of the saturation percentage of Gavur Lake soils is different and higher than the values of Amik Lake and Golbasi Lakes.

It was determined that there is a significant negative ($p<0.01$) relationship between the total number of fungi and soil reaction. Many studies have indicated that there is a negative relationship between the amount of fungi in the soil and the soil reaction, regarding the numbers of microorganisms in both arid and rainy seasons. Because; it is found that the total number of fungi in the soil is the highest when the soil's pH is low and the soil is acidic; and many species of fungi can develop in these soils and they form the dominant flora [30]. Rousk et al. [31] in the research conducted in North and South America on arable lands; indicated that soil pH is associated with soil microorganisms and fungus concentration increases at low pH. They have indicated that fungal populations exhibit optimal growth and development at the maximum level at 4.5 pH value, and are less affected by pH and have a weaker relationship with it. This finding was supported by Aciego-Pietri and Brookes [32]. Vineela et al. [14], in a study conducted in semi-arid regions of India; have reported that, the microbial activity and especially the number of fungi have increased in environments where soil pH is low. Deslippe et al. [33], reported a negative correlation between the total amount of microorganisms and the soil reaction in their research, indicating that microbiological activity decreased at high pH.

It is stated that there is a significant negative ($p<0.1$) relationship between the total number of fungi and the volume weight of soil. Similar findings were reported by Li et al. [34]; in the experimental farm of Henan Agricultural University in China; that there is a negative correlation between volume weight and number of fungi in corn-cultivated soils; and the increase in volume weight negatively affects microorganism numbers and microbial activity. It was determined that there is a significantly positive ($p<0.5$, $p<0.1$, $p<0.1$) relationship between the total number of fungi and the wet aggregate stability, and between plastic limit and liquid limit values. Soil microorganisms show better growth in the soil with a good aggregate structure. In the research conducted by Kadioglu [35] on the lands of Tuzcu and Tepe villages, it was determined that from the topographic positions of peak point to the foothill, aggregate stability and total number of the fungi have increased.

As a result of the correlation analysis, it was determined that there was a significant positive correlation ($p<0.01$) between the total number of bacteria and the total number of total algae and total actinomycetes. Balasooriya et al. [9]; at the study on the wetland in the northern part of Bourgoyen-Ossemeersen in Belgium; have stated that, the amount of bacteria and the amount of actinomycetes increases, as the depth increases. It was stated that there was a significant positive correlation ($p<0.5$, $p<0.1$) between total bacterial count, and soil saturation percentage value and amount of organic matter. Soil organic matter is the source of nutrients for microorganisms in the soil. In particular, the soil organic matter consists of all the vegetative and animal carcass materials and their transformed products in and on the mineral soil. Naturally, as the level of organic matter increases, microbial activity will naturally increase. Morrissey et al. [36], in their search near Chesapeake Bay (Virginia); have stated that soil organic matter and active microbial activity in the soil are proportional to each other and there is a very strong positive correlation between them. Jeanneau et al. [37] and Kadioglu [35] found that there is a positive correlation between soil organic matter and microorganism amount. They stated that there is a high number of bacteria in the soil where the soil organic matter content is high and there is a positive relation between them.

It was found that there is a significant positive correlation ($p<0.01$) between the total number of algae and the total number of actinomycetes. Anand et al. [38], in their study at Canada in the Ontario region on the soil of industrial air pollution near Sudbury; Reported a positive correlation between total blue green algae and total actinomycetes numbers at $p<0.05$ significance level. It was found that there was a significant negative correlation ($p<0.01$) between the total number of algae and the soil reaction, and a significant positive correlation ($p<0.01$) between the total number of algae and the soil organic matter value (Figure 3). Lombard et al. [39] reported that microorganism structure in the soil and soil function are related to some physical and chemical properties such as soil pH and organic matter content.

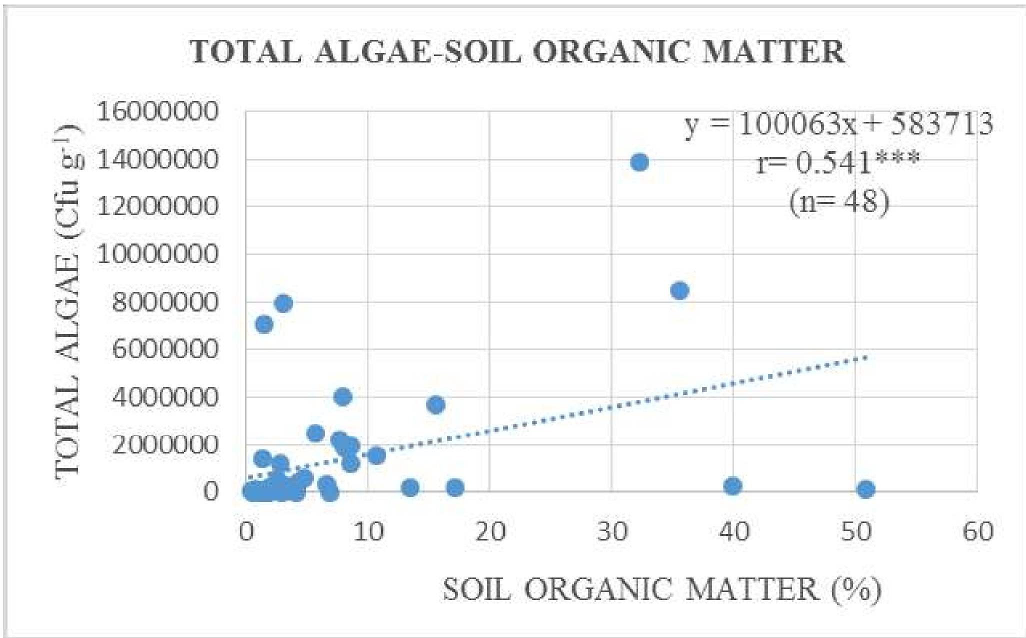

FIGURE 3
Relationship between total algae and soil organic matter

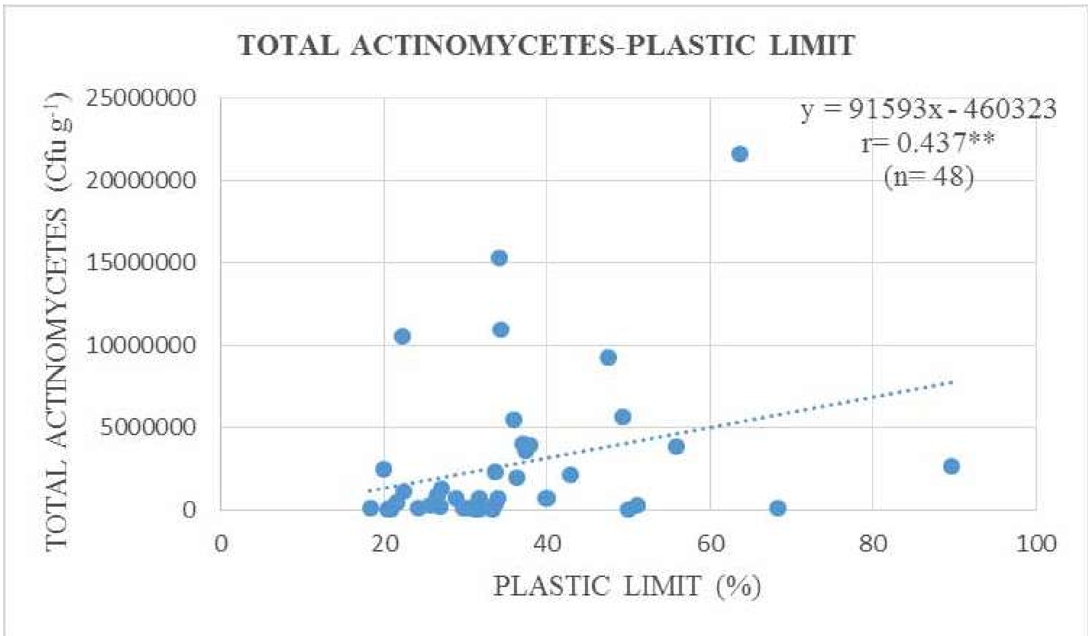

FIGURE 4
Relationship between total actinomycetes and plastic limit

Organic matter has a great effect on microorganisms by being basic nutrients in the soil, and serving nutrients to plants. Rousk et al. [15] reported that soil pH is associated with soil microorganisms, and it has been found that some microorganisms and algae are abundant in mild acid and slightly alkaline soil.

As a result of the correlation analysis made in the soil; ($p<0.5$, $p<0.01$) between the total number of actinomycetes in the soil and the percentage of saturations and organic matter values. In Gokcan's work [40] in Amasya Suluova, it has been observed that there is a linear increase in microbial activity due to the increase of organic matter in the soil. However, as the profile is followed to the lower layers; It has also been reported that there is a decrease in the microorganism population depending on organic matter and nutrient reduction. A significant negative ($p<0.5$, $p<0.1$) relationship was found between the total actinomycete number and the volume weight of the soil and the hydraulic conductivity value. In Li et al.'s study [34] conducted in China, similar findings indicated that there was a negative correlation between volume and actinomycete numbers in cultivated land and that the increase in volume was negatively affecting the number of microorganisms and microbial activity. A significant positive correlation ($p<0.5$) was found between the total number of actinomycetes and the plastic limit and the liquid limit as the result of the correlation analysis (Figure 4).

One way analysis of variance was performed on the distributions of microorganisms in the first two horizons of Amik Lake, Gavur Lake and Golbasi Lakes soils, and the logarithmic transformation is applied to give the assumptions of the variance analysis. The difference between total fungus and total algae counts of Gavur and Golbasi Lakes soils was not statistically significant. The total number of fungi and total algae of Amik Lake soils were found to be different and lower than the values of the other two lake area soils. The difference between the total number of fungi and algae in the soil of Amik Lake and the soil of these two lake areas was statistically significant ($p<0.05$). It is stated that the difference in statistics between total bacteria and total actinomycet numbers of the Amik, Gavur and Golbasi Lakes soils is not significant. Organisms respond very quickly to soil and environmental changes. Udotong et al. [30] reported that the number of microorganisms in soil samples taken during the rainy season is higher than the population of microorganisms in the dry area, in the study of microbiological and physico-chemical field on the wetland soil in the Eketan city of Nigeria. Especially the high level of groundwater level of the Amik Lowland soils from the research area can be shown as the reason for the microorganism population to be lower than the other lake areas. Microorganisms that provide soil biologic activity provide soil fertility in a variety of forms. It is known that some rocks, especially serpentine, release the toxic elements (nickel, cadmium) that prevent plant life and at the same time inhibit microbial life [1]. By Abaci Bayar [10], it is stated that, limestone rich in calcium and serpentine rich in magnesium are widely found in the research areas of Amik, Gavur and Golbasi Lakes. It is thought that the alterable magnesium contents of Amik Lake is different and higher than the content of magnesium of Gavur and Golbasi Lakes, because of the more widespread serpentin-derived rocks in this area. It is known that in the regions of Islahiye, Hassa and Kirikhan, where lowland is fed with surface waters, serpentine rocks are widespread and many mining operations, where chromium mine is excavated, are found. Along with these findings; the fact that the presence of serpentine is dominant in the soil of Amik Lake, reveals that the population of microorganisms is lower. This data shows how wetland lands, which are intended to be included in agricultural production and use, are transformed into low-productivity soils.

When the research area in the open-water zone soils of the lakes are considered; all the microorganism groups in Gavur and Golbasi Lake area were found to be quite higher than the soils of Amik Lake; and the difference between the significant groups was examined by Duncan multiple comparison test and given in Table 2. Although the difference between the total number of algae of the Gavur and Golbasi Lakes is not statistically significant, the difference between the total number of algae of the Amik Lake and the other two lakes is statistically significant ($p<0.05$). It is known that, at the top of the main nutrition sources of microorganisms are the organic matter found in the soil. As stated by Abaci Bayar [10], the organic matter levels of the soils of Golbasi and Gavur Lakes (5.44%, 11.42%) are higher than the organic matter value of the soil of Amik (1.23%), which makes it possible to find higher microorganism populations in this soil. The productivity of soils is closely related to the level of keeping soil organisms. Along with the transformation of nutrients into the form that they can be used by the plants, the soil fertility ensures that many physical and chemical conditions are at suitable levels for plant breeding. The low level of organic matter in the soil affects the microbial activity, which causes the productivity of the soil to decrease or disappear. From this point of view, the productivity of Amik lowland soils is less than that of Golbasi and Gavur Lake lands. The fertility of the Amik lowland's soils, which began degradation many years ago, was observed at lower levels than the Gavur Lake and Golbasi soils that underwent less degradation. In addition the correlation table of some microbiological, physical and chemical analyzes made in the study area is shown in Table 3.

TABLE 2
Multiple comparison test of the microbiological properties of the soil in the lake open-water zone (Duncan Test) results

Area	Number	Fungi cfu g^{-1}	Bacteria cfu g^{-1}	Algae cfu g^{-1}	Actinomycete cfu g^{-1}
Amik Lake	6	4.6746±0.817	5.4240±0.341	4.6030^{b}±0.908	6.0038±0.579
Gavur Lake	8	5.2576±0.784	5.4782±0.553	5.1375^{a}±1.044	6.1308±0.846
Golbasi Lakes	16	5.2781±0.605	5.6476±0.916	5.8241^{a}±0.992	6.2055±0.896
Sig.		p<0.197	p<0.778	p<0.039	p<0.879

The average values shown in the same column with different symbols according to Duncan test was statistically significant at $p\leq0.05$.

TABLE 3
Correlation chart of microbiological, physical and chemical analyses made in soil

	TF	TB	TA	Tac	SP	OM	AP	pH	Db	WAS	Ks	PL	LL
TF	-												
TB	0.343*	-											
TA	0.487***	0.593***	-										
Tac	0.525***	0.592***	0.753***	-									
SP	0.555***	0.285*		0.366*	-								
OM	0.432**	0.390**	0.541***	0.506***	-	-							
AP	0.306*	-	-	-	-	-	-						
pH	-0.526***	-	-0.484***	-	-	-	-	-					
Db	-0.427**	-	-	-0.360*	-	-	-	-	-				
WAS	0.329*	-	-	-	-	-	-	-	-	-			
Ks	-	-	-	-0.381**	-	-	-	-	-	-	-		
PL	0.413**	-	-	0.437**	-	-	-	-	-	-	-	-	
LL	0.414**	-	-	0.362*	-	-	-	-	-	-	-	-	-

TF=Total fungus; TB=Total bacteria; TA=Total algae; Tac=Total actinomycete; SP=Saturation percentage; OM=Organic matter; AP=Available phosohorus; pH=Soil reaction; Db= Volume weight; WAS= Wet aggregate stability; Ks= Hydraulic conductivity; PL=Plastic limit; LL= Liquid limit

CONCLUSIONS

Wetlands are one of the most important ecosystem types of the earth with their natural functions and economic values, balancing the water regime of the environment, regulating the climate, realizing the highest of the world's carbon retaining function after the tropical forest and oceans, hosting many living creatures, and having extremely high biological productivity.

In this study, attempts were made to determine the changes occurring as the result of the applications on the three wetlands extending in the Eastern Mediterranean Region. These three wetlands are listed as Amik Lake in the south, Gavur Lake in the north, and Golbasi Lakes in the north. The elevation of the region increases from south to north, reaching 478 m in Gavur Lake basin and 885 m in Golbasi basin, while the height of the Amik basin is 83 m from the sea. The biological characteristics of a total of 48 soil samples in both the lake area and the lake open-water area of the research areas were examined, and the findings were evaluated, and the sizes of soil degradation in each field were compared in terms of microbial values. Although the difference between total fungus and total algae numbers of Gavur and Golbasi Lakes area is not statistically significant, the difference between total fungus and total algae counts of Amik Lake and two other lake areas is statistically significant. Firstly, it was observed that microbial activity decreased in Amik Lake soil, where the most degradation was occurred by drying, and total amount of fungi, bacteria, algae and actinomycetes were found to be at their lowest values. Microbial life is prevented because of the reasons such as the high level of groundwater level of the Amik Lake area soil, the widespread availability of serpentine, which is rich in magnesia, in the area. It is known that serpentine rocks are common in Islahiye, Hassa and Kirikhan regions, where lowland is fed with surface runoff waters, and many mining operations, from which chromium mine is extracted, are found. The amount of total algae was found to be the highest in the Golbasi Lakes, which partially retained their wetland characteristics. The Gavur Lake, which is moderately degraded, has the highest levels of total fungi, bacteria and actinomycetes in the soil. When the microorganism values of the soils of the lake open-water zone are examined statistically; although the difference between the total number of algae of the Gavur and Golbasi Lakes lands is not statistically significant; the difference between the total number of algae of the Lake Amik and the other two lakes is statistically significant. As the organic matter level of the Golbasi and Gavur Lake lands is higher than the organic matter level of the Amik Lake soils; populations of microorganisms in the soil were also found at higher levels. The extremely low microbial activity of the Amik Lake soils, which is one of our most important wetlands that have been dried and cultivated, has been assessed as a sign that the productivity of these soils are at low levels.

Amik Lake; depending on the beginning of the drying of its soils before the other lake areas; has lost its wetland characteristics due to the high level of mineralization and degradation in the soil. Despite there is a spatial increase in the agricultural land in this area, which is opened to agriculture by drying; it is concluded that, today, the fertility of the soil is in low levels regarding the crop production considering the many negative features present in the soil, and there also will be problems in the future. The area that is started to be dried in the second place was the wetland of Lake Gavur. Because of the inadequacy of the drainage channels in the ground, it is observed that; the soils were under the water during a significant part of the year, the progress that had been expected from the agricultural production couldn’t be achieved, and after all, it lacked the economical and natural contributions of the lowlands as it had lost its lowland characteristics. The result was that the Golbasi Lakes soils, which had the least soil degradation, maintained their wetland characteristics at a better level than the other lake areas.

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CORRESPONDING AUTHOR

Ahu Alev Abaci-Bayar
Soil Science and Plant Nutrition Department,
Kirsehir Ahi Evran University,
Agricultural Faculty,
Kirsehir, 40200 – Turkey

e-mail: ahuabaci@gmail.com