Egypt. J. Soil. Sci. **Vol. 59**, No. 3, pp. 285-303 (2019)

Egyptian Journal of Soil Science
http://ejss.journals.ekb.eg/

Functional Microbial Diversity in Relation to Soil Characteristics and Land Uses of Wadi Um Ashtan Basin, North-western Coast, Egypt

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THE OBJECTIVE of this study was to survey the soil and assess the functional microbial diversity in relation to soil physicochemical characteristics and land uses of a representative watershed basin in the NW coastal region of Egypt. The area is classified, on basis of remote sensing as well as GIS facilities, into four (4) major landforms i.e. coastal plain, wadi course, piedmont plain, and plateau table land. Twenty (20) soil profiles, representing those landforms, were morphologically described, their physical and chemical characteristics and land uses were determined; and their diagnostic characteristics were assessed. Results indicated that soils generally belong to the order *Entisols* and could be placed, at sub-group level, to *TypicTorrifluvents, TypicTorriorthents,* and *Lithic Torrorthents*. Also, Topsoil samples were collected from the mentioned twenty sites and evenly distributed over the entire watershed. They were analyzed for physical and chemical characteristics and the colony forming units (cfu) of nitrogen fixers, phosphate solublizers, cellulose, protein and starch decomposers were estimated. Soil enzyme activities (dehydrogenase, nitrogenase, urease, protease, cellulase, amylaseand phosphatase) were determined and Shannon and Simpson's diversity indices were used. The results based on statistical analysis showed significant correlation between "the studied soil characteristics and land uses" and "soil microbial groups and enzyme activities" of the study area.The findingsof Shannon and Simpson indices of the studied microbial groups and enzyme activities indicated that the coastal plain soils have moderate functional diversity, soils of wadi course and piedmont plain have the largest functional diversity, and the lowest diversity indices were recorded in soils of the plateau table land. Correlation analysis showed that land uses was positively correlated with urease activity and negatively correlated with nitrogenase activity. In addition, microbial activities and population were negatively affected by gravel, calcium carbonate, hydrogen ion and salinity and positively affected by organic matter. The study outputs could support sustainable land management and participatory agricultural development process for rainfed agriculture in Egypt.

Keywords: Wadi Um Ashtan, Soil characteristics, Land use, Functional microbial diversity, Enzyme activity, Spatial analyses, GIS.

Introduction

The North Western coastal region of Egypt extends 500 km from west of Alexandria to the Libyan border and is unique in similarity of its geomorphic units where mainly occupied with three major geomorphic units, *i.e.* coastal plain, piedmont plain and plateau and composed essentially of sedimentary rocks that belong to the Teriatory and Quaternary ages. The strata, from the sea coast to plateau, were formed of a calcareous formation of Pliocene, Pleistocene and Holocene ages and covered by recent aeolian and fluvial sediments. Those three geomorphic units are dissected by 218 wadis having different size, morphometric characteristics, vegetative cover, aspect and slope gradient. From those wadis, wadi Um Ashtan that faces many challenges

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DOI: 10.21608/ejss.2019.14096.1282
Received 27/6/2019; Accepted 25/8/2019
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like those found in the similar arid areas of the Middle East since the area has a fragile natural resource base and offers limited alternatives for sustainable increases in agricultural productivity under rainfed conditions.

The variability of almost all soil characteristics is the final result of dynamic interactions among several natural environmental factors [i.e., climate, parent material, living organisms, and topography] (Jenny, 1941).

Soil microorganisms are necessary for ecosystem functioning and key drivers for the nutrient cycling in soils (Hogberg et al., 2001 and Van der Heijden et al., 2008). Besides, they are involved in soil fertility, detoxification, remediation and waste decomposition, as well as water purification (Kremen, 2005).

Soil microorganisms establish less than 0.5 % (w/w) of the soil mass, andhave a key role in soil characteristics and formation. They have a major effect on the cycling of elements, most of which are essential for the growth of living organisms. They participate in several processes such as oxidation, nitrification, ammonification, nitrogen fixation, and other processes which lead to decomposition of soil organic matter and releasing essential inorganic plant nutrients to the soil. Therefore, microbes are important to maintain a productive and valuable soil system. Disruption of the soil environment, such as land use dissimilarity or soil cultivation, can shift microbial communities and can have detrimental effects on soil nutrient cycling (Rillig and Mummey, 2006; Gessner et al., 2010 and Chaparro et al., 2012).

Processing and recovery of nutrients areessential tasksfor microbial activity in soils that require a diverse number of extracellular enzymes, making them a suitable estimator of microbial activity and diversity (Caldwell, 2005 and Sinsabaugh et al., 2008). Due to the substrate specificity nature of enzymes, measuring potential activities of soil enzymes involved in nutrient cycling can give insight into conversion processes of organic and inorganic compounds. Extracellular soil enzyme activity can be related to wide range of soil characteristics, such as soil biogeochemical properties (Amador et al., 1997) or community structure (Waldrop et al., 2000), and the scale of spatial resolution in range from landscape scale (Decker et al., 1999; Gallo et al., 2004 and Waldrop et al., 2004) to the size of soil particle fractions (Kandeler et al., 1999).

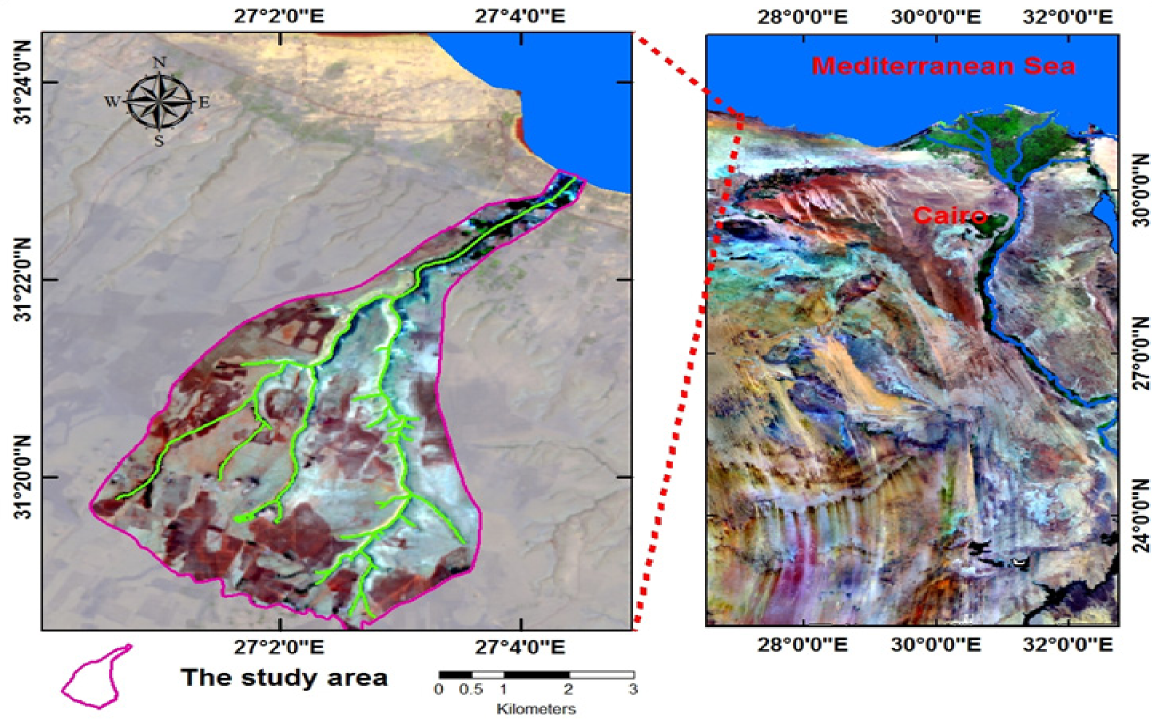
The diversity of functions within a microbial population is essential for the multiple functions of a soil. The functional diversity of microbial communities are very sensitive to environmental changes (Kandeler et al.,1999). Functional diversity of microbial populations in soil may be estimated by either expression of different enzymes (carbon utilization patterns - extracellular enzyme patterns) or diversity of nucleic acids within cells. Indicators of functional diversity arealsomarksofmicrobialactivityand thereby integrate diversity and function.

The soil microbial diversity is broad, and it is assessed that about 99% of species still unidentified (Fierer, 2017), and since little is known aboutsoil microbial diversity and soil characteristics and land uses influencing it in the North Western coastal region of Egypt, so the study was carried out to survey the soils and assess the microbial diversity in relationto soilphysic-chemical characteristics and land uses of a representative watershed basin in the NW coastal region of Egypt.

Description of The Study Area

Wadi Um Ashtan is situated in the north western region of Egypt and 14 km west of Marsa Matrouh city and extends 9.5 km south from the coast between latitudes 31° 18` 25`` and 31° 23` 06`` N and longitudes 27° 00` 27`` and 27° 04` 33`` E, with a total area of about 5727.7 feddans, out of which more than 2262.1 feddans are cultivated land, (Map 1). The floor slopes generally downwards to the north eastern direction from 130 m above sea level to sea level. The climate is Mediterranean with the mean annual rainfall of about 120 mm. Soils' parent materials have been mainly formed during Pleistocene and Holocene ages of the recent era as surficial flood sediments of a calcareous formation, EGPC- Conco Coral, (1987).

The distribution of soil types depends on lithology, relief and depth of bed rocks. The main cultivated crops in wadi Um Ashtan are fruit trees (olive andfig) and cereals (barley and wheat) as well as some limited areas of vegetables. Crop cultivation is mainly depending on rainfall in the study area.



Map 1. Location of the study area (wadi Um Ashtan basin), North Western Coast of Egypt

Materials and Methods

To survey soils and assess the microbial diversity in relation to soil physic-chemical characteristics and land uses of a representative watershed - wadi Um Ashtan basin - in the NW coastal region of Egypt, the methodology involved the following:

- False Color Composite (FCC) Landsat 8 Operational Land Imager (OLI) 2018 (path 179 and row 38)obtained from USGS (2018) was used to identifythe spatial distribution of land use types in wadi Um Ashtan, (Fig. 1). It was also merged and processed with Digital Elevation Model (SRTM) of 30 meter resolution obtained from USGS (2018) to identify the spatial distribution of the different land forms of the study area. The satellite data were digitally rectified and enhanced using the ERDAS Imagine 16.5. (ERDAS Inc., 2018). Image enhancement was done to improve the visual interpretability of an image by increasing the apparent distinction between the features. The process of visually interpreting of digitally enhanced imagery attempts to optimize the complementary abilities of the human mind in interpreting spatial attributes of image and identifying obscure or subtle features (Lillesand and Kiefer, 2000). Contrast stretching was applied on the used image and false color composites (FCC) was produced and visually interpreted using on screen digitizing in order to delineate land useclasses.For better classification results,Normalized Difference Vegetation Index (NDVI) was also applied to classify the Landsat image at a resolution of 30 m.

- Accuracy of land cover/land use mapping of the image was carried out using 150 points, 100 checkpoints from field data and 50 points existing on topographic map dated 1983. The location of the 150 points was chosen using random stratified method to represent different land cover/land use classes of the area. To increase the accuracy of land cover/land use mapping of the image, ancillary data and the result of visual interpretation was integrated with the classification result using GIS.

- The OLI data were classified using the ISO-DATA classification technique (Map. 2) to produce unsupervised soil map for the resultant landforms (Lillesand and Kiefer, 2000).

- A rapid reconnaissance survey was made throughout wadi Um Ashtan basinin Jan and Feb, 2018 to help identify and verify landforms, the broad soil patterns, landscape characteristics and the spatial distribution of soil classification units. The primary mapping units were verified based on the field interpretation.

- Twenty soil profiles were dug to represent unsupervised soil mapping unit within the resultant landformsdepending on a particular combination of major land uses and soil characteristics andapproximately distributed over the entire watershed basin.

- The GPS coordinates of locations were registered and imported to GIS software as point map.A detailed morphological description of soil profiles was recorded on the basis of guidelines for soil description (FAO, 2006).

- The collected soil samples from genetic horizons/ layers of the profile pits were subjected to some physical and chemical analyses using the soil survey laboratory methods manual, USDA (2014a).

- One topographic sheet (Egyptian Military Survey Authority, 1984) of 1:25,000 scale pertaining the study area was used for geo-referencing of satellite image, creation of the study area map, validation of the ground truth, delineationof boundaries and transport network.

- ERDAS Imagine 16.5 (ERDAS Inc., 2018) and the ArcGIS 10.5 (ESRI, 2017)software were used as the main GIS packages for analyzing, processing and mapping.

- Collection tools were washed with water, followed by disinfection with 70% alcohol and 2% sodium hypochlorite and, finally, were washed thoroughly with sterile water.

- With regard tocollectingsamples, the site was cleaned superficially to remove plants and decomposing organic matter.The collected soil samples were transferred to sterilized Falcon tubes and kept on ice or refrigerated and taken for laboratory analysis.

- The collected surface soil samples from the studied soil profiles sites were also used for microbial isolation to estimate the colony forming units (cfu) of nitrogen fixers, phosphate solublizers,cellulose, protein and starch decomposers. The techniques used for isolation were serial dilution and spread plate method. Jensen's medium (Jensen, 1951), Picovskay's medium (Pikovskaya, 1948), congo red agar medium (Hendricks et al., 1995), skim milk agar medium (Uyar et al., 2011) and starch agar medium (Atlas et al., 1995) were used for isolation and counting the number of nitrogen fixers, phosphate solublizers,cellulose, protein and starch decomposers, respectively.

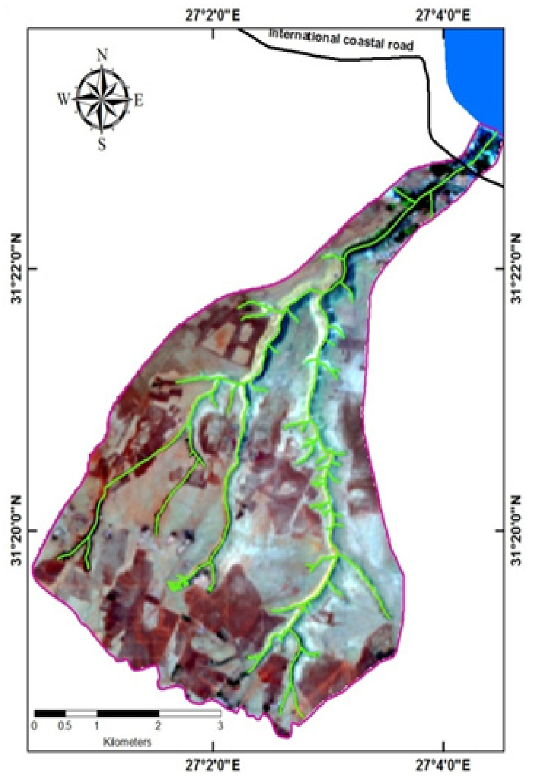
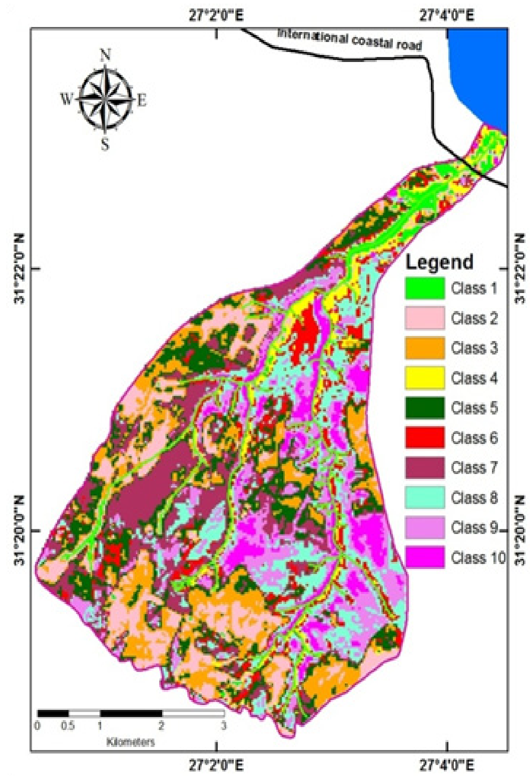


Fig. 1. FCC Landsat 8 OLI image acquired in 2018 (bands 7, 5, 3) of wadi Um Ashtan basin, North Western Coast of Egypt



Map 2. Unsupervised classification of the study area (wadi Um Ashtan basin), North Western Coast of Egypt

- With regard to determining soil enzyme activities - Klein et al. (1971) method was used to measure dehydrogenase activity, Döbereiner et al. (1972) method to measure nitrogenase activity Kandeler and Gerber (1988) method to measure urease activity, Pokhrel et al. (2014) to measure protease activity, Guan et al. (1986) method to measure cellulase activity (Bernfeld, 1955) method to measure amylase activity, and Tabataiand Bremner (1969) method to measure phosphatase activity.
- The Shannon andSimpson's reciprocal diversity indices were used (Hill et al., 2003) and calculated by the DOTUR program (Schlosset al., 2005) to evaluate the microbial diversity.
- The functional diversity of enzyme activities was calculated using Simpson–Yule index (SYI) equation $SYI = \Sigma(pi)2$, (Bending et al., 2004), and Shannon's diversity index (Lagomarsino et al., 2011) equation

$$H=-\sum ki=1piln(pi)$$

where piis the ratio of the activity of each enzyme to the sum of the activities of all enzymes.

- A statistical analysis for data to determine the correlation between different study factors (microbial communities counts and enzyme activities) and both of soil characteristics and land use types was conducted by SPSS 21.1 software program (SPSS, 2014).

Results And Discussion

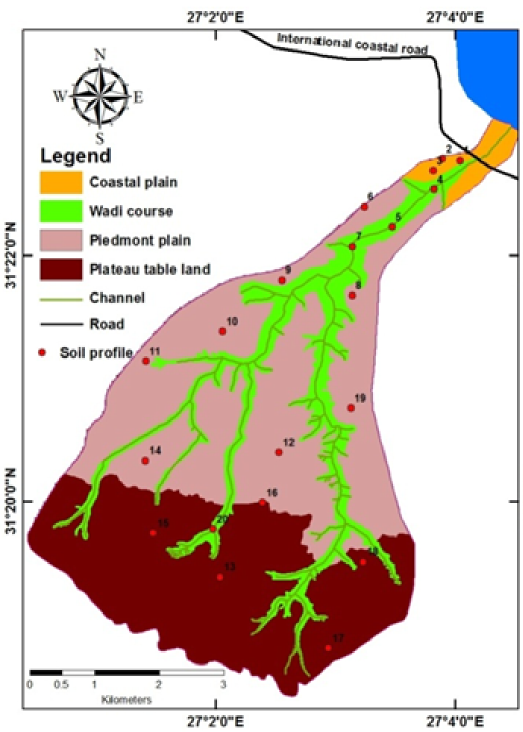
Soil characteristics of the study area

Results of the visual interpretation of the merging between Digital Elevation Module (DEM) and Landsat-8 OLI image in false colour composite bands 3,5, and 7 together with knowledge drawn from topographic map and field investigations indicated that the area covered by the present study could be divided into four major landforms (main geomorphic units); namely coastal plain,wadi course, piedmont plain, and plateau table land,(Map3).

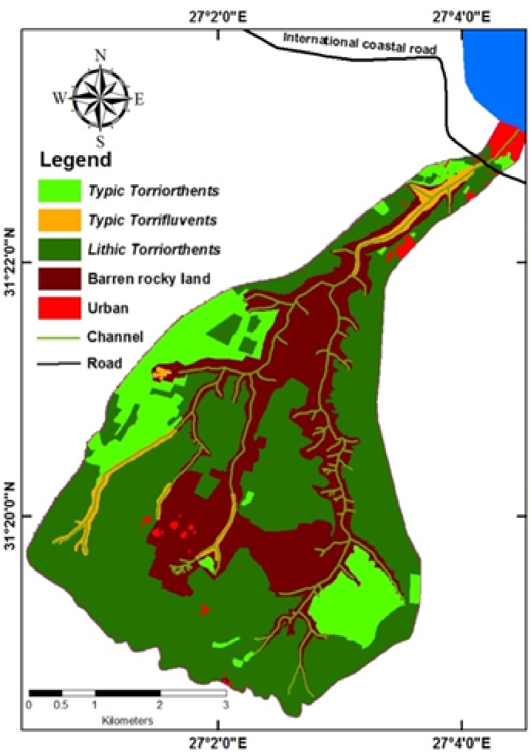
The principal results of the main morphological features, physical and chemical soil characteristics obtained of the four major landforms are shown in Table (1), classified according to Soil Taxonomy (Map 4), (USDA Soil Survey Staff, 2014b) and discussed as follows:

Soils of the coastal plain

Soils of this unit were formed down the limestone plateau landscape in the northern part of the study area, formed from Quaternary



Map 3. Main landforms represented by soil profiles of the study area (wadi Um Ashtan basin), North Western Coast of Egypt



Map 4. Soil classification of the study area (wadi Um Ashtan basin), North Western Coast of Egypt

TABLE 1. The selected morphological features, physical and chemical soil characteristics of representative soil profiles in Wadi Um Ashtan basin, North Western Coast of Egypt.

Prof. No.	Lat. N Log. E	Topography, Slope	Surface cover (RF)*	Land use	Depth (cm)	Gravel (%) > 2 mm	Texture class	$CaCO_3$ %	pH	EC dSm^{-1}	ESP %	OM %
Coastal plain												
1	31°22’46.04” 27° 4’2.57”	Almost flat, Nearly level	None	Olive trees intercropped with vegetables	0-30	10.9	SL	28.3	7.9	1.4	4.74	1.7
					30-50	20.6	SL	23.7	7.9	1.5	8.33	1.6
					50-90	5.4	SL	15.2	8.6	0.9	9.23	2.5
					90-150	3.0	SL	32.9	8.7	1.0	9.61	2.2
2	31°22’46.80” 27° 3’53.63”	Almost flat, Nearly level	Common fine gravel	Cereal crops	0-25	9.0	SL	32.1	7.5	0.5	8.68	2.6
					25-50	4.8	SL	41.0	8.0	0.8	9.88	2.5
					50-90	2.7	SL	55.3	7.9	2.1	9.60	2.7
					90-150	1.2	SL	56.2	7.9	3.2	8.01	2.1
3	31°22’41.03” 27° 3’48.88”	Almost flat, Nearly level	Many varysized gravel	Natural range land (desert shrubs)	0-25	32.2	SL	21.8	7.7	1.4	4.74	2.7
					25-60	28.1	SL	25.4	7.8	2.2	8.33	1.5
					60-120	34.1	SL	40.3	7.4	3.1	9.23	2.1
Wadi course												
4	31°22’31.93” 27° 3’49.23”	Gently undulating, Gently sloping	Very few fine gravel	Fig trees with grass in-between	0-30	0.9	SL	19.1	7.4	0.6	12.00	3.4
					30-70	1.4	SL	23.1	7.8	0.4	13.00	2.9
					70-150	9.6	SL	35.1	8.0	0.3	14.50	2.3
5	31°22’13.56” 27° 3’28.45”	Gently undulating, Gently sloping	Few fine gravel	Olive and Fig trees with grass in-between	0-45	3.6	SL	26.5	7.5	0.8	12.82	2.9
					45-75	12.3	SL	26.5	8.2	0.3	9.72	2.5
					75-150	3.2	SL	26.6	7.8	0.3	14.20	2.4
7	31°22’4.15” 27° 3’8.56”	Gently undulating, Gently sloping	Very few fine gravel	Fig trees with grass in-between	0-30	4.0	SL	21.4	7.6	0.5	12.00	2.7
					30-60	9.0	SL	22.1	8.1	0.6	13.60	2.4
					60-90	10.0	SL	26.0	8.2	0.5	6.50	2.1
20	31°19’46.50” 27° 1’58.56”	Gently undulating, Gently sloping	Common fine gravel	Fig trees with grass in-between	0-30	2.8	SL	20.8	7.5	0.7	14.50	3.3
					30-70	3.9	SL	26.8	7.8	0.3	14.10	3.1

TABLE 1. Cont.

Prof. No.	Lat. N Log. E	Topography, Slope	Surface cover (RF)*	Land use	Depth (cm)	Gravel (%) > 2 mm	Texture class	$CaCO_3$ %	pH	EC dSm^{-1}	ESP %	OM %
Piedmont plain												
6	31°22’23.44” 27° 3’14.59”	Almost flat, Nearly level	Common varysized gravel	Cereal crops	0-30	7.4	SL	16.2	7.8	0.4	7.1	3.1
8	31°21’40.36” 27° 3’8.38”	Almost flat, Nearly level	Many varysized gravel and limestone	Natural range land (few desert shrubs)	0-30	17.0	SL	18	7.7	1.1	8.0	2.5
9	31°21’51.10” 27° 2’28.47”	Almost flat, Nearly level	Many varysized gravel and limestone	Natural range land (few desert shrubs)	0-25	15.3	SL	16.3	7.8	1.0	7.9	3.0
10	31°21’26.55” 27° 1’58.35”	Gently undulating, Gently sloping	Many varysized gravel and limestone	Natural range land (few desert shrubs)	0-35	6.1	SL	14.6	7.6	5.4	8.2	2.0
11	31°21’8.26” 27° 1’25.08”	Almost flat, Nearly level	Common varysized gravel	Cereal crops	0-30 30-55	3.2 10.0	SL	10.5 12.5	7.7 7.8	0.7 2.7	7.1 8.2	0.7 1.1
12	31°20’23.89” 27° 2’31.74”	Almost flat, Nearly level	Common varysized gravel	Cereal crops	0-20 20-45	13.3 15.0	SL	23.6 39.8	7.8 8.0	0.6 1.1	7.3 8.3	1.8 1.9
14	31°20’19.75” 27° 1’24.70”	Gently undulating, Gently sloping	Common varysized gravel and limestone	Natural range land (few desert shrubs)	0-25	7.7	SL	14.8	7.8	0.7	7.2	2.3
19	31°20’45.40” 27° 3’7.68”	Almost flat, Nearly level	Common varysized gravel	Cereal crops	0-25 25-50	3.7 8.8	SL	21.6 28.9	7.8 7.9	0.8 3.4	9.2 11.3	2.6 2.8
Plateau table land												
13	31°19’23.22” 27° 2’2.24”	Almost flat, Nearly level	Many varysized gravel	Cereal crops	0-20 20-40	2.9 14.8	SL	20.8 15.2	7.8 7.6	6.1 13.1	9.04 6.58	2.2 2.2
15	31°19’44.55” 27° 1’28.60”	Almost flat, Nearly level	Common varysized gravel	Cereal crops	0-25 25-45	2.1 8.7	SL	19.7 18.1	7.7 7.7	1.4 3.2	7.64 5.11	2.9 1.5
16	31°19’40.33” 27° 2’35.68”	Almost flat, Nearly level	Common varysized gravel and limestone	Natural range land (few desert shrubs)	0-25 25-50	33.3 5.3	SL SL	32.3 21.1	7.7 7.8	5.8 3.1	7.91 7.70	2.0 2.2
17	31°18’48.61” 27° 2’56.65”	Almost flat, Nearly level	Many varysized gravel	Cereal crops	0-30 30-50	8.0 33.3	SL SL	23.6 26.3	7.8 8.0	0.6 1.5	10.10 13.00	2.1 2.2
18	31°19’30.61” 27° 3’14.01”	Almost flat, Nearly level	Common varysized gravel	Natural range land (few desert shrubs)	0-30 30-55	17.7 1.9	SL L	22.5 52.7	8.0 7.9	7.4 20.2	9.14 6.54	2.1 2.7

deposits during Pleistocene and Holoceneages. They occupy an area of about 98 feddan covering 1.7 % of the total area and represented by soil profiles No. 1, 2 and 3. The surface is almost flat, sloping towards the north, and covered with gravel ranging widely from none to many fine gravel. Surface runoff and associated hazard of water erosion are slight due to dominant very gentle slope. The data show that, because of the depositional process, soil profiles are deep (> 100 cm) and lack any evidence of development. Characteristics of soils formed on it are mainly related to the local lithology.

Soil texture is sandy loam throughout the different layers of representative soil profiles. Calcium carbonate content ranges between 15.2 and 56.2 % with a general trend to increase in the profile bottoms reflecting the calcareous parent materials nature in the representative profile. Secondary formations of carbonates and gypsum in detectable amount were identified throughout the layers without any diagnostic horizons. Soil-pH ranges from slightly alkaline to alkaline (pH 7.5 – 8.6), ESP values indicate low sodium hazard (ESP 4.74 - 9.88 %), and soil salinity varies from free to very slightly saline (EC 0.5 – 3.2 dSm^{-1}). The vertical distribution of salts shows gradual homogeneity with depth. Organic matter content was low as values ranged from 1.5 to 2.7 %. The soils of this unit are classified as *TypicTorriorthents.*

Soils of the wadicourse

Soils of wadi Um Ashtan course occupy an area of about 158.3 feddan representing 2.8% of the total area. Drains start cutting the upper calcareous plateau in which soils formed over eroded limestone. Sediments moved downward along the stream and forming soils with depth increasing. Soils have dense vegetation cover of rainfed olive and figtreesand vary in their characteristics according to stream location.Surface is gently undulating, gently sloping and covered with gravel ranging from very few to common.

Soils of this landform were examined through profiles 4, 5, 7, and 20. Soils formed on middle and upper streamsare mostly shallow to moderately soil depth with sandy loam texture. Contrarily, soils in the downstream areas have deep profileswith sandy loam texture throughout the different layers of representative soil profiles. Calcium carbonate content ranges between 19.1 and 35.1% with a general trend to increase in the profile bottoms reflecting the calcareous parent materials nature in the representative profiles. Secondary formations of carbonates and gypsum in detectable amount were identified throughout the layers without any characteristics of diagnostic horizons. Soil reaction is slight tending to moderately alkaline, where pH values fluctuate between 7.4 and 8.2. Soils are none saline with low EC values ranging from0.3 and 0.8 dSm^{-1}. Values of ESP (from 6.5 to 14.5 %) indicate with values of EC and pH that those soils are none saline. Organic matter content in the representative soil profiles ranged from 2.1 % to 3.4 % with irregular decrease with depth. Hence, soils are classified as *TypicTorrifluvents* (profiles 4, 5, 7 and 20)

Soils of the piedmont plain

Soils of the piedmont plain cover an area of 2001 feddan representing 34.9 % of the total area. The surface is almost flat to gently undulating topographyand covered with common to many varysized gravel and limestone. They are represented by soil profiles No. 6, 8, 9, 10, 11, 12, 14, and 19. These soils are characterized by shallow or moderate deep sandy loam profile with imperfectly drained (profiles-6, 8, 9, 10, 12, 14, and 19) and moderately well drained (profiles-11) status. Calcium carbonate content ranges between 10.5 and 39.8% with a general trend to increase in the profile bottoms reflecting the calcareous parent materials nature in the representative profiles. Secondary formations of carbonates in detectable amount were identified throughout the layers with no any characteristics of diagnostic horizons. The electrical conductivity values revealed that soil salinity is mostly very slightly saline (EC < 5.4 dS/m). The soil-pH values vary from slightly (pH ≈ 7.6) to moderately alkaline (pH ≈ 8). ESP values (from 7.1 to 11.3%) indicating with the other parameters (pH and EC) that these soils are mostly very slightly saline.Organic matter content was as low as from 0.7 to 3.1 %. Hence, they are classified as *TypicTorriorthents*(profile-11) and *Lithic Torriorthents*(profiles-6, 8, 9, 10, 12, 14, and 19).

Soils of the plateau table land

Soils of this unit cover an area of about 1769.9 feddan, representing 30.9 % of the total area and are represented by soil profiles No. 13, 15, 16, 17 and 18. They are formed from calcareous formation of Pliocene age. The surface is almost flattopography andnearly level slope towards the north, and is covered with common or many varysized gravel and limestone fragments. The hazardous effect of water erosion is slight as surface runoff is very slow due to very slight slope class. Data in Table 1 show that soils represented by profiles 13, 15, 16 and 17 are shallow deep while profile 18 is moderate deep and all are characterized by sandy loam to gravelly sandy loam texture with imperfectly drained (profiles-13, 15, 16, and 17) and moderately well drained (profile-18) and devoid of any sign of horizon development. Total carbonates ranged from strong to extreme ($CaCO_3$ ≈ 15.2 - 52.7%), soil-pH is slightly to moderately alkaline (pH 7.6-8.0), ESP values indicate low sodium hazard (ESP 5.11- 9.14 %), and soil salinity varies widely from very slightly to extremely saline (EC 0.6 – 20.2 dSm^{-1}). Organic matter content was low as values ranged from 1.5 to 2.9 %. Based on analytical data and field studies, soils of the plateau table land are classified as *TypicTorriorthents* (profile- 18) and *LithicTorriorthents* (profiles-13, 15, 16, and 17).

Land uses of the study area

The false color compositeimage of 2018 was visually interpreted using on screen digitizing to classify the image into different land use units that were recognized and mapped, (Map 5). Based on the field observation in Jan and Feb, 2018 and measurements resulted from the visual interpretation, the study area was classified into 3 agro-ecological zones having specific attributes of geomorphic characteristics, land use patterns and socio-economic implications and containing 5 land use units distributed over the entire watershed basin that were marked and abrupt as shown in Table 2.

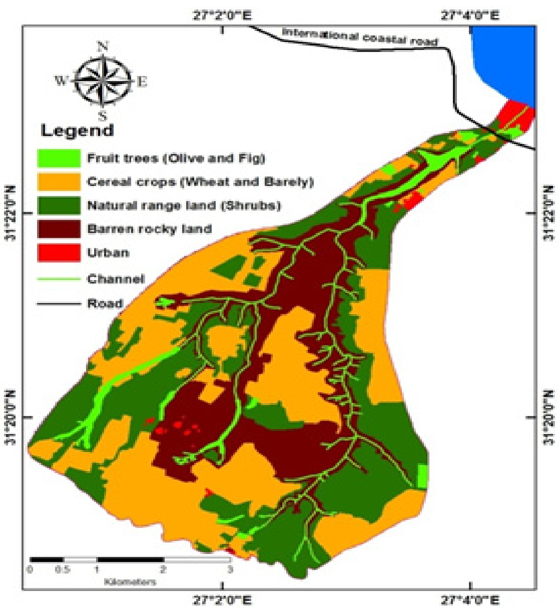
The land uses in the three ecological zones were as follows:

Zone One: (the coastal plain) extends up 1.6 km from the coast line with the deepest soils and the higher rainfall. Farming system was mostly fruit trees (olive and fig) in the main stream bed of wadi Um Ashtan besides some cereals fields, limited intercropping vegetables and small ruminant.

Zone Two: (the piedmont plain) stretches from 1.6 to 7 km with more cereals and fewer trees in the main stream bed.

TABLE 2. Area and percentage of land use classes of the study area

Class name	Area in winter 2018	
	Feddan	%
Fruit trees (Olive and Fig) intercropped with vegetables	204.0	3.6
Cereal crops (Wheat and Barely)	2058.0	35.9
Natural range land (Shrubs)	1764.4	30.8
Barren rocky land	1619.4	28.3
Urban	81.9	1.4
Total	5727.7	100



Map 5. Land use classes of the study area (wadi Um Ashtan basin), North Western Coast of Egypt

Zone Three: (the plateau table land) stretches from 7 to 9.5 km with predominant cereals (wheat and barley plants), scattered natural grazing areas and small population of sheep and goats.

Functional microbial communitiesof the study area

The principal reults of the different physio-chemical soil characteristics and land uses obtained from the representative surface soil samples in Jan, 2018 and shown in Table (3) were used to assess the functional microbial diversity and identify the correlation between them.

Populations of nitrogen fixers, phosphate dissolving bacteria, cellulose, protein and starch decomposers were counted and presented in Table (4) and their distribution ratios were graphically presented in Figure (2). Results have indicated that the microbial communities varied insoils of the four landforms of wadi Um Ashtan basin. The microbial communities of the coastal plain soils were less diverse according to Shannon H (3.6-5.7), and Simpson 1/D (17.7-31.6) diversity indices as shown in Table (6).The majority of microbial populations were belong to phosphate dissolving bacteria (44%) while starch decomposer recorded the lowest counts (8%). This may because the low organic matter and high calcium carbonate content of these soils.

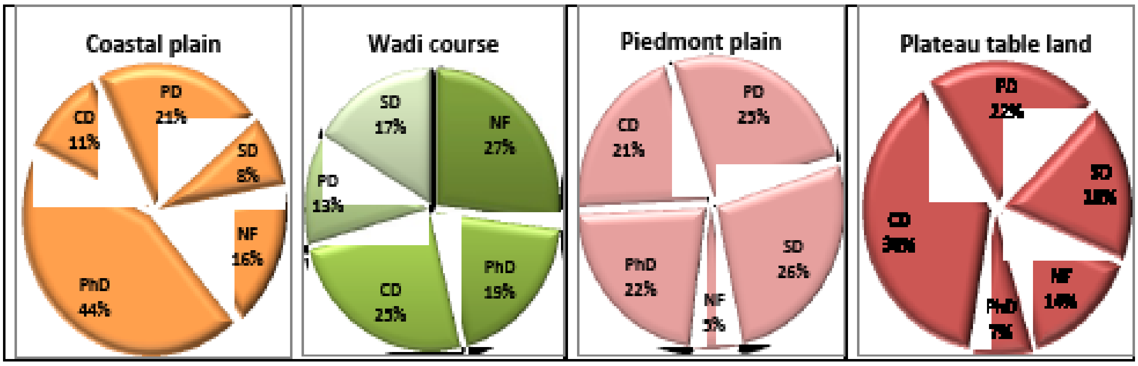
Soils of the wadi course supportedbetter microbial diversity when compared with other landforms(H 5.2-6.3, and 1/D 25.7-36.3).It has convergent ratios of microbial communities and can be arranged as follows; nitrogen fixers (27%) > cellulose decomposer (25%) > phosphate dissolving bacteria (19%) > starch decomposer (17%) > protein decomposer (13%). It may be due to that the soils of this landform were none saline and their organic matter content was relatively high.

Soils of the piedmont plain exhibited good microbial diversity of studied microbes(H 4.1-7.8, and 1/D 22.4-47.5), except for counts of nitrogen fixers which were very low and represent only 5%. The lack in nitrogen fixer populations may be due to that soils belong to this landform have imperfectly drained, and shallow or moderate deep.

Soils of the plateau table land supported low microbial diversity (H 2.8-4.5 and 1/D 14.9-21.1) and the counts of cellulose decomposer were the greatest and represent about 38% while the

TABLE 3. Land uses and selected physiochemical characteristics of the studied soil sites at wadi Um Ashtan, Noth coastal region, Egypt

Site No.	Land use	Gravel %	Texture	$CaCO_3$ %	pH	E C dS/m	O M %
1	Olive trees	10.9	Sandy Loam	28.3	7.9	1.4	1.7
2	Cereal crops	9.0	Sandy Loam	32.1	7.5	0.5	2.6
3	Natural range land	37.2	Sandy Loam	21.8	7.7	1.4	2.7
4	Fig trees	0.9	Sandy Loam	19.1	7.4	0.6	3.4
5	Olive and Fig trees	3.6	Sandy Loam	26.5	7.5	0.8	2.9
6	Cereal crops	7.4	Sandy Loam	16.2	7.8	0.4	3.1
7	Fig trees	4.0	Sandy Loam	21.4	7.6	0.5	2.6
8	Natural range land	17.0	Sandy Loam	18	7.7	1.1	2.5
9	Natural range land	15.3	Sandy Loam	16.3	7.8	1.0	3.0
10	Natural range land	6.1	Sandy Loam	14.6	7.6	5.4	2.0
11	Cereal crops	3.2	Sandy Loam	10.5	7.7	0.7	0.7
12	Cereal crops	13.3	Sandy Loam	23.6	7.8	0.6	1.8
13	Cereal crops	2.9	Sandy Loam	20.8	7.8	6.1	2.2
14	Natural range land	7.7	Sandy Loam	14.8	7.8	0.7	2.3
15	Cereal crops	2.1	Sandy Loam	19.7	7.7	1.4	2.9
16	Natural range land	33.3	Sandy Loam	32.3	7.7	5.8	2.0
17	Cereal crops	8.0	Sandy Loam	23.6	7.8	0.6	2.1
18	Natural range land	17.7	Sandy Loam	22.5	8.0	7.4	2.1
19	Cereal crops	3.7	Sandy Loam	21.6	7.8	0.8	2.6
20	Fig trees	2.8	Sandy Loam	20.8	7.5	0.7	3.3



(a) (b) (c) (d)

Fig. 2. Percent of soil microbial communities (nitrogen fixers NF, phosphate dissolving PhD, cellulose decomposer CD, protein decomposer PD and starch decomposer SD) ofwadi Um Ashtan landforms, North Western Coast of Egypt

TABLE 4. Microbial communities counts of surface soil samples at wadi Um Ashtan basin

Site No.	Microbial communities counts (×10³cfu*/g dry soil)				
	Nitrogen fixers	Phosphate dissolving	Cellulose decomposer	Protein decomposer	Starch decomposer
1	4.5	8	5	1	0
2	6	28	2	0.4	5
3	4	1.5	2	0.4	2.5
4	8.5	15	13	0.5	18
5	30	6.5	22	0.8	1
6	7	11	18	0.6	10
7	9	6	10	1.2	3
8	0	14	8	1.3	27
9	0	14	8	1.2	27
10	0	20	3.5	0.1	9
11	5.5	0	5	2.5	2
12	3	3.5	9	1.6	8
13	4.5	0	2	0.9	0
14	3.5	13	0	1.8	13
15	7	7	14	1.5	13
16	2.5	1.5	10	0.01	4.5
17	4	1	11	0.2	6
18	1.5	0	11	0.1	0
19	2	6	26	0.3	3
20	15	17	12	0.4	16

* cfu: colony forming units

populations of phosphate dissolving microbes represent only 7%. This may be due to that soils of this land form have mostly gravely texture, relatively high salinity, low organic matter and high calcium carbonate content in many areas.

Soil enzyme activities of the study area

Soil enzyme activities are mainly of microbial origin, being derived from intracellular or extracellular enzymes. Enzymes were chosen on their rapport with the microbial activity (dehydrogenase), nitrogen (nitrogenase, urease and protease), carbon (cellulase and amylase), and phosphorus (phosphatase) cycling and were used as indicators of functional diversity in soil. Dehydrogenase activity of surface soil samples ranged from 1.13 to 3.97µg TPF/g dry soil/h, with a mean of 2.35µg TPF/g dry soil/h. Nitrogenase activity ranged from nil to 81.5µg NH_4^+-N/gdry soil/h, with a mean of 7.40µg NH_4^+-N/gdry soil/h. Urease activity ranged from 10.9 to 60.7µg C_2H_4/gdry soil/h, with a mean of 35.82µg C_2H_4/gdry soil/h. Protease activity ranged from 7.80 to 38.11 µg tyrosine/g dry soil/h, with a mean of 16.39µg tyrosine/g dry soil/h. Cellulase activity ranged from 0.87 to 2.43µg glucose/g dry soil/h, with a mean of 1.45µg glucose/g dry soil/h. Amylase activity ranged from nil to 3.5µg glucose/g dry soil/h, with a mean of 1.57µg glucose/g dry soil/h. Phosphatase activity ranged fromnil to 32.5µg p-nitrophenyl phosphate/g dry soil/h, with a mean of 8.53µg p-nitrophenyl phosphate/g dry soil/h. The coefficients of variance (CV) were 42% for dehydrogenase activity, 279.5% for nitrogenase activity, 41.3% for urease activity, 44.5% for protease activity, 28.5% for cellulase activity, 76.2% for amylase activity, and 96.8% for phosphatase activity (Table 5).

The results of the present study indicated that enzyme activity varied considerably within the studied soil samples. The maximum dehydrogenase activity was recorded in soil samples numbers 4, 6, 9, 14 and 20. It might be due to more bacterial population numbers, increasing of organic matter, and low salt concentration of those sites.

Soil dehydrogenase activity reflects the oxidative activity of soil microorganism; it occurs in all viable microbial cells and functions as a good indicator of the metabolic state of soil microbes (Järvan et

TABLE 5. Enzyme activities of surface soil samples at wadi Um Ashtan basin

Site No.	Dehydrogenase µmole TF/g dry soil/h	Nitrogenase µmole c2h4/g dry soil/h	Urease µmole NH-^{4} N/g dry soil/h	Protease µmole tyrosine/g dry soil/h	Cellulase µg glucose/g dry soil/h	Amylase µg glucose/g dry soil/h	Phosphatase µmole p-nitrophenyl phosphate/g dry soil/h
1	1.48	0.68	18.6	14.02	1.59	0	4
2	2.10	1.5	19.2	12.40	0.87	1.2	32.5
3	1.68	0.29	55.1	14.45	0.96	0	3
4	3.30	6.3	34.3	15.20	1.31	2.3	20.3
5	2.60	81.5	31.1	18.18	0.97	2.1	6
6	3.97	0.28	31.5	14.10	1.46	1.7	12.5
7	1.30	3.03	33.8	22.69	1.82	1.8	5.5
8	3.99	0	35.5	11.89	1.24	3.3	14.6
9	3.97	0	35.6	11.83	1.22	3.2	14.5
10	1.72	0	40.9	10.03	0.97	2.9	7
11	1.85	0.48	10.9	38.11	1.04	2.5	8.5
12	1.17	0.14	40.5	28.21	1.31	0	2
13	2.28	0.21	25.5	16.21	1.64	0	0
14	3.51	0.58	20.2	19.18	1.40	3.5	12.5
15	1.37	0.16	55.9	15.64	1.77	1.73	8
16	1.13	0.22	57.9	7.80	2.09	0.94	0.5
17	1.80	1.98	55.7	10.56	1.67	0.76	0.5
18	2.33	0.16	60.7	9.11	1.61	0	0
19	2.08	0.23	33.3	13.88	2.43	1.04	2.5
20	3.64	50.2	20.2	24.62	1.72	2.6	15.5
Mean	2.35	7.4	35.82	16.39	1.45	1.57	8.53
CV*	42	279.5	41.3	44.5	28.5	76.2	96.8

* CV: Coefficient of variance

al., 2014 and Bhaduri et al., 2017). Data in Table (5) also revealed that soil samples numbers 5 and 20 had the highest nitrogenase activity whereas the highest urease activity was recorded in samples numbers 3, 15, 16, 17 and 18 and maximum protease was in sample number 11. Nitrogenase, urease and protease activities are involved in N-cycle, urease and proteaseare involved in the decomposition of organic N compound degradation by hydrolyzing C-N bonds of amide. The urease enzyme is responsible for hydrolyzing of urea and producing ammonia, urease in soils is rapidly decomposed by protease enzyme (Chen et al., 2011).The highest cellulase activity was recorded in samples numbers 16 and 19 and the maximum amylase activity was noted in samples numbers 8, 9 and 14. Cellulase and amylase enzymes are involved in C cycle and play an important role in the hydrolytic processes that take place during organic matter breakdown (Riah et al., 2014; Malik et al., 2017 and Xue et al., 2018). The highest phosphatase activity was recorded in sample number 2, Phosphatase enzyme is involved in soil P cycling. It is sensitive to environmental changes, thus may be a suitable selection to determine soil quality (Turgay et al., 2010).

Shannon and Simpson indices of enzyme activities showed that the soils of coastal plain had moderatefunctional diversity (H 0.84-1.33 and 1/D 1.75-3.07) whereas soils of wadi course and piedmont plain hadthe largest functional diversity according to Shannon H (1.22-1.51 and 0.94-1.51), and Simpson 1/D (2.54-3.67, 2.2-3.86) respectively.The lowest diversity indices (H 0.63 - 1.05 and 1/D 1.45 - 2.28) were recorded in soils of plateau table land (Table 6).

TABLE 6. Diversity indices of microbial communities and enzyme activities of surface soil samples at wadi Um Ashtan basin

Site No.	Shannon H’		Simpson (1/D)	
	Microbial communities	enzyme activities	Microbial communities	enzyme activities
1	5.5	1.27	30.4	2.89
2	5.7	1.33	31.6	3.07
3	3.6	0.84	17.7	1.75
4	6.3*	1.51*	36.3*	3.67*
5	5.2	1.22	25.7	2.54
6	5.7	1.37	30.7	3.14
7	5.7	1.32	29.5	2.87
8	5.6	1.36	29.4	3.12
9	5.6	1.34	29.4	3.01
10	4.8	1.12	22.4	2.20
11	5.5	1.21	28.7	2.43
12	4.1	0.94	22.4	2.20
13	4.2	0.99	23.5	2.28
14	7.8*	1.51*	47.5*	3.86*
15	4.5	1.05	21.1	2.08
16	2.9	0.69	14.7	1.46
17	3.6	0.84	16.7	1.65
18	2.8	0.63	14.9	1.45
19	5	1.15	23.9	2.33
20	6*	1.51*	32.4*	3.70*

*higher number indicates more diversity

TAPLE 7. Spearman correlation coefficient (r) between soil characteristics and their uses and counts and activities of microbial communities of surface soil samples at wadi Um Ashtan basin

		Land use	Soil characteristics					
		Gravel %	Texture		pH	EC dS/m	OM %	
Functional microbial communities	Nitrogen fixers	-.784**	-.628**	-	.125	-.525*	-.518*	.474*
	Phosphate dissolving	-.110	-.173	-	-.355	-.462*	-.427*	.467*
	Cellulose decomposer	-.391	-.361	-	.128	-.102	-.204	.453*
	Protein decomposer	-.159	-.419	-	-.414	.087	-.265	-.446
	Starch decomposer	.174	-.113	-	-.488*	-.289	-.340	.484*
Enzyme activates	Dehydrogenase	.109	-.132	-	-.467*	-.029	-.161	.534*
	Nitrogenase	-.708**	-.498*	-	.288	-.490*	-.515*	.484*
	Urease	.513*	.403	-	.162	.142	.388	-.015
	Protease	-.325	-.549*	-	-.237	-.237	-.421	.524*
	Cellulase	-.239	-.208	-	.178	.293	.096	.411
	Amylase	.137	-.298	-	-.684**	-.446*	-.227	.430
	Phosphatase	-.149	-.289	-	-.442	-.563**	-.487*	.548*

* Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level.

Soil microbial groups and enzyme activitiesin relation tosoil characteristicsand land uses

The relation betweensoil characteristics and land usesof the study area andsoil microbial groups and their enzyme activities wasestimated using Spearman correlation coefficient (Table 7).The results showed high negative correlation between land use and nitrogen fixer counts (r = -0.784) whileother studied microbial groups were lesscorrelated to land uses. Also, land useshavesignificant positive relationwithurease activity (r =0.513), and strong adverserelation withnitrogenase activity (r=-0.708),whereas dehydrogenase, protease, cellulase, amylase and phosphatase enzymes were less correlated with land use. These results are in line with Zhalnina et al. (2013) who reported that the counts of ammonia oxidizing-archaea were positively correlated to agriculture practices, while diazotrophicsymbiont was negatively correlated toagricultural management andBomfim*et al*., (2018) who observed complex non-linear relationship between diazotrophs counts and land uses. Also, these agree with Brandan*et al*., (2019) who found a modification in the abundance of the microbial groups involved in N cycling with long term crop rotation compared to the monoculture.

Among the studied soil characteristics, organic matter had the strongest relation with the microbial communities and their activities. There was a significant positive relationship between organic matterand all the studied microbial groups, it had also significantly adverse relation with protease activity (r=-0.524) and was significantly positive with the activities of dehydrogenase (r=0.534), nitrogenase (r=0.456) and phosphatase (r=0.548), indicating the activation of soil microorganisms by the addition of the organic amendments. These results agree with Lori et al. (2017) and Aziz et al. (2018) who reported that soil organic matter enhance the microbial biomass of soil and hence increase soil enzyme activities. Chukwuma et al. (2018) recorded a high negative relationship between protease activity and organic matter during his work on the investigation of the variation in the activities of some soil enzymes during phytoremediation of agricultural soil polluted by crude oil.

Gravel content had a highly significant adverse relation with the populations of nitrogen fixers (r=-0.628), nitrogenase activity (r=-0.498) and protease activity (r=-0.549).These results agree with Najmadeen et al. (2010).

Calcium carbonate content had a significantly adverse relation with starch decomposer populations (r=-0.488), activities of dehydrogenase (r=-0.467) and amylase which was very significantly correlated with calcium carbonate concentration (r=-0.684). This is due to that most of α-amylases are metalloenzymes and require calcium ions for their activity, whereas the high concentrations of calcium ion inhibited amylase activity (Yuk et al., 2008). Also, Giel and Bojarczuk (2011) observed a negative correlation between dehydrogenase activity and calcium content suggesting that the increased calcium ion resulted in osmotic stress and affecting the microbial activities.

pH had a significant adverse relationship with the populations of nitrogen fixers (r=-0.525) and phosphate dissolving bacteria (r=-0.462). It had also a significant negative relation with the activities of nitrogenase (r=-0.490), phosphatase (r=-0.563), and amylase (r=-0.446). Many studies showed that microbial populations were significantly and negatively correlated with soil pH (Ghorbani-Nasrabadi et al., 2013; Błońska et al., 2017; Li et al., 2018 and Choudhary et al., 2018). Most of microbes have narrow pH ranges for their optimal growth. Also, enzyme activities depend on pH (Rousk et al., 2010).

The counts of nitrogen fixers and phosphate dissolving bacteria, nitrogenase and phosphatase activities were significantly negative correlated with soil EC (r=-0.518, -0.427, -0.515 and-0.487, respectively).These results agree with other researchers who observed high levels of microbial population in soils with low salinity levels comparable to high salinity levels (Stomeo, et al., 2013;Yan et al., 2015; Fang et al., 2017 and Kathia et al., 2018). Salinity causes a reduction in microbial activity and microbial biomass. Also, it changes microbial community structure. High concentrations of soluble salts decrease the soil water potential resulting in low soil microbial activity and plasmolysis of some microbial cell due to osmotic stress and toxic ions (Rietz and Haynes, 2003).

Conclusion

The study dealt mainly with surveying the soil and assessing the functional microbial diversity in relation to soil physicochemical characteristics and land uses of a representative watershed basin in the NW coastal region of Egypt. The present study indicates the following:

1- The study area has four major landforms (main geomorphic units) namely coastal plain, wadi course, piedmont plain, and plateau table land, some of them showed detectable amount of secondary formations of carbonates throughout some layers without any characteristics of diagnostic horizons. So, they are classified as TypicTorrifluvents, TypicTorriorthentsand Lithic Torriorthents. It is concluded that there is no relationship between the geomorphic units and the existed soil taxa.

2- With regard to land uses, the study area was classified into 3 agro-ecological zones containing 5 land use units distributed over the entire watershed basin i.e. fruit trees (olive and fig) intercropped with vegetables, cereal crops (wheat and barley), natural range land (shrubs), barren rocky land and urban.

3- The studied soil physicochemical characteristics (ravel, $CaCO_3$ content, pH, salinity and organic matter) and land uses are related to soil microbial groups and their enzyme activities at the study area.

4- The activities of nitrogen fixers were the most affected by changes in soil physicochemical characteristics and land uses. Soils of moderate CaCO3 content induce the growth and activities of starch decomposer.

5- It is essential to recognize the effects of the most important components of soil characteristics and land uses on Microbial diversity and in turn their effects on soil management in North - Western Coast of Egypt.

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التنوع الميكروبي وعلاقته بأنواع التربة واستخدامات الأراضى لحوض وادى أم أشطان - الساحل الشمالى الغربى - مصر

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الهدف من إجراء هذة الدراسة هو حصر بعض خواص التربةوتقييم التنوع الميكروبى الوظيفى وعلاقته ببعض خواص التربة الفيزيوكيميائية وإستخداماتها لأحد الأوديةالممثلة لإقليم الساحل الشمالى الغربى لمصر (حوض وادى أم أشطان). وبناءاً على التحليل الطيفى للمرئية الفضائية Landsat 8 OLI مع التحليل الطبوغرافى للنموذج الرقمى للإرتفاعات بإستخدام GISوالدراسة الحقلية والتحليلات المعملية ، أمكن تمييز عدد (4) وحدات أشكال أرضية رئيسيةلمنطقة الدراسة هى السهل الساحلى ومجرى الوادى والسهل البيدومونتى وسطح الهضبة. تم حصر خواصأراضى المنطقة بإستخدام 20 قطاع أرضى ممثل للاختلافات الطيفية لسطح التربة للأشكال الأرضية واستخداماتها السائدة بها ووصفت مورفوبيدولوجيا، وتم تجميع عينات التربة منها لإجراء التحليلات المعملية اللازمة لتقدير صفات وخصائص التربة الطبيعية والكيميائية، كما أمكن تقسيم تربة هذه الأشكال الأرضية السائدة لعدد (3) تحت مجموعة عظمى طبقا للتصنيف الأمريكى الحديث هى:-

Lithic Torriorthents - TypicTorrifluvents - TypicTorriorthents

كما تم تحليل الـ 20 عينه التربة السطحية لذات المواقع المأخوذ منها قطاعات التربة ميكروبيولوجيا لتقدير أعداد الميكروباتالمثبتات للنتروجين والمذيبات للفوسفات ومحللات السليولوز والبروتين والنشا بالأضافة إلى أنه تم تقدير الأنشطة الأنزيمية لميكروبات التربة (ديهيدروجينيز ، ونيتروجينيز ، واليوريز ، والبروتييز ، والسليوليز ، والأميليز ، والفوسفاتيز) كما تم تقدير دليل التنوع الميكروبى لشانون وسيمبوسون. وأظهرت النتائج بصفة عامة (إعتماداً على التحليل الأحصائى) على وجود علاقة أرتباط معنوية بين خواص التربة المدروسه وإستخدامات أراضى الوادى الزراعية وغطائها الخضرى الطبيعى وذلك مقابل المجموعات الميكروبية بالتربة وأنشطتها الأنزيمية. كما أوضحت النتائج أن أدلة التنوع الميكروبى لشانون وسيمبسون للمجموعات الميكروبية والأنشطة الأنزيمية فى تربه السهل الساحلى ذات تنوع ميكروبى وظيفى متوسط بالمقارنة بتربة كلا من مجرى الوادى والسهل البيدومونتى بينما ترية سطح الهضبة كان التنوع الميكروبى الوظيفى بها منخفض. كما أظهرت النتائج وجود علاقة إرتباط ايجابي بين إستخدامات الأراضى ونشاط إنزيماليوريز وارتباط عكسى مع نشاط إنزيمالنيتروجينيز. بالأضافة إلى أن المجموعات الميكروبية وأنشطتها الأنزيمية تأثرت عكسيا بمحتوى الحصى وكربونات الكالسيوم ودرجة الايون الهيدروجيني والملوحة الزائده في حين أن المجموعات الميكروبية وأنشطتها الأنزيمية تأثرتايجابيا بمحتوى المادة العضوية. وأن مخرجات الدراسة تدعم إدارة الأراضى المستدامه وعمليات التنمية الزراعية التشاركية فى الزراعات المطرية فى مصر.