Original Research Article

Evaluation of Drainage Water for Suitability of Irrigation Purpose in Egypt

Ahmed Ibrahim Mohamed[1] and Ezzat Rashad Marzouk[2*]

[1]Soil and Water Department, Faculty of Agriculture, Suez Canal University, Ismaila, 41522, Egypt

[2]Division of Soil and Water, Faculty of Environmental Agricultural Sciences, Arish University, North Sinai, 45516, Egypt

*Corresponding Author's E-mail: ahmed_shabaka@yahoo.com
Phone: (+20)-1010035003

Abstract

The study comprised of evaluation water quality of El-Wadi drain of Ismaillia, Egypt for irrigation purpose. Water samples from fifty locations along El-Wadi drain stream were collected, approximately one sample every 1 km, and analyzed for pH, electric conductivity (EC), Na, Ca, Mg, K, Cl, CO_3, SO_4, Cu, Fe, Ni and total phenols. Results showed a significant correlation (p < 0.01) between ions of Cl and Na (r = 0.92), Ca (r = 0.86) and Mg (r = 0.88), which were found the form of Cl-Ca/-Mg/-Na complexes in the drain water. In addition, sodium adsorption ratio (SAR), adjusted SAR (Adj SAR), adjusted sodium ratio ($Adj.R_{Na}$), residual sodium carbonate (RSC) and exchangeable sodium percentage (ESP) were found average of 4.35, 8.42, 4.75, -1.90 and 5.13, respectively. Irrigation water classes are used for salinity (EC) and sodium hazards to assess water suitability for irrigation, and it is found that samples categorized in three classes; (i) 18 % in the class of C2S1, (ii) 76 % in the class of C3S, and (iii) 6 % in the class of C3S2 indicating good to acceptable quality for irrigation with some cautions in case of last water class. Furthermore, the trace metal analysis indicated some degree of restriction on the use of this water for irrigation due to elevated Ni concentrations that associated with intensive and moderately cultivated areas. Unfortunately, the drainage water are restricted for direct irrigation purposes because of toxic organic compounds contaminations (phenol compounds; average of 82.9 ± 32.1 μgl^{-1}) that exceeded the Egyptian permissible limits. This finding may confirm the need of including organic and inorganic element analyses in routine work for water quality determination for irrigation purpose.

Keywords: Drainage Water, Irrigation, Water Properties, Water Quality

INTRODUCTION

The world population increased from 2.5 billion in 1950 to 5.3 billion in 1990 and it was expected to reach 8.5 billion in 2025 (UN, 1991 and CAPMAS, 2016). Consequently, the need of increasing agricultural production will be also required to maintain the present level of food intake through which water demand for irrigation will be necessitated. Arid and semi-arid zones are often suffering from both saline ground water, and insufficient of fresh water to meet the irrigation demand (Sharma and Tyagi, 2004). The gap between growing population, and demand for irrigation water of suitable quality will certainly be challenging issue in the near future (Alexakis et al., 2011 and Abd El-Motaleb et al., 2017).

Egypt is a semi-arid country where Nile River is the main water source for domestic, industrial and agricultural usesbut there is a severe shortage of good quality surface irrigation water.Egypt is faced with water-scarcity situations due to limit water resources for a rapidly increasing population, expansion of the irrigated area, and water competition by neighbor countries.

Generally speaking, the actual water resources currently available for use in Egypt are: (i) Nile River; 55.5 BCM (billion cubic meters)yr^{-1}, effective rainfall on the northern strip of the Delta; 1.3 BCM yr^{-1} and non-renewable groundwater for western desert and Sinai; 2 BCM yr^{-1}. However, water requirement for different sectors in Egypt is 79.5 BCM yr^{-1} (Ahmed, 2017 and Alaa, 2015). The gap between the need and availability of water is about20 BCM yr^{-1}, thus alternative source of water has to be explored. Egypt already conserves water through increasing irrigation water use efficiency and reuse of agricultural drainage water for irrigation. It is estimated that about 7 BCM of agricultural drainage water in the Nile Delta is yearly reused, and it is predicted to reach 8.9 BCM by 2017 (MWRI, Egypt, 2005 and 2014). However, most data available on water uses in Egypt are approximate and are not based on field measurement because of the lack of measuring devices with accepted accuracy for the water uses for either irrigation or the municipal and industrial sectors (Allam, 2007 and Mohamed et al., 2017).

Water quality assessment and understanding of the factors affecting water quality are very important baselines from which effective management and sustainable development of water resources could be properly achieved. According to Allam et al. (2015), agricultural drainage water reuse in Egypt is the most promising, immediate, and economically attractive option to make more water available for agriculture purposes. Additional benefit of this practice is the more nutrient availability in soil, which were present in the drainage water (Mohamed et al., 2017). However, alongside the benefits of nutrient availability there is clearly a hazard associated with the use of drainage water on soil health as a source of irrigation water. As drainage water comes from passing through the soil and drainage network, it picks up salts, agricultural chemicals, and other pollutants such as phenols produced from use of numerous pesticides (Barnes, 2012). Moreover, the drainage networks in Egypt, unfortunately, receive substantial amount of domestic and industrial wastewater and therefore, may pose a significant source of contaminants (Allam et al., 2015). On the other side, the farmers do not know about the potential for pollution from such irrigation waters and ignore possible risks to the food chain and environment.

Therefore, it is imperative to quantify water quality parameters of drainage water. Water quality criteria for agricultural purpose should provide information on the suitability of water for irrigation use. The quality of water used for irrigation can vary greatly in quality depend upon type and quantity of dissolved salts (Richards, 1954; Todd, 1959; Stevens, 1962; Walton, 1970; Rijtema, 1981; Ayers and Westcot, 1985). Van Horn (1971) found that factors, which are necessary in studying water quality, are total dissolved salts, ionic composition, and concentration of trace elements.

Rijtema (1981) recorded that characteristics of irrigation water that appears to be most important in determining its quality are; total concentration of soluble salts; chloride concentration; relative proportion of sodium to other cation; concentrations of specific ions that may be toxic to plant. The majority of the studies were focused either on determining the trace metal concentrations or on quantify ordinary water quality parameters. However, according to few other studies had tried to combine water quality parameters with the additional measurement of phenol compounds. Ultimately, given the demands for agriculture from an expanding population, it will be necessary to undertake analysis of the advantages and hazards of using drainage water in irrigation. Furthermore, using remote sensing data and GIS data analysis to produce land use land cover (LULC) maps is an important data source for finding the relationship between different concentrations of the trace elements and the phenolic components and LULC classes (Abdel Kawy and Abou El-Magd, 2012; Badreldin and Goossens, 2013; Bakr et al., 2010).

As agricultural soils are subjected to be irrigated with drainage water, therefore, this study was focused that whether irrigation with drainage water is potentially dangerous or advantageous to soil health, plant productivity and human health with respect to the impact on water quality, heavy metal loading and total phenol content. To achieve these objectives, fifty water samples were collected from El-Wadi drain, Ismaillia, Egypt and assessed for irrigation suitability.

MATERIALS AND METHODS

Site description

The study area, El-Wadid rain in Ismailia governorate is named in relation to the valley's biggest Tomellat Valley area covers Ismailia and the Sinai. This drain thrown annually 0.5 BCM of agricultural drainage water in Temsah Lake, one of the Great Lakes associated with the Suez Canal. The total length of El-Wadi drain is 55 km. El-Wadi drain start from El-Kasasin city (30º 33' 26.37" N, 31 º 56 ' 23.66" E) and ended at Temsah Lake (30º 34' 28.77" N, 32 º 16 ' 42.03" E). Ismailia climate is generally moderate all over the year. Rain falls in winter; it does not exceed 50 mm yr^{-1}. The average minimum and maximum air temperature are 13.7°C and 27.9°C, respectively. Relative humidity varies from 38 to 63% coinciding with the dry and wet seasons, respectively. (Fig. 1)

Water sampling and analytical procedures

Fifty different water sampling locations of El-Wadid rain were selected to cover the whole drain (approximately
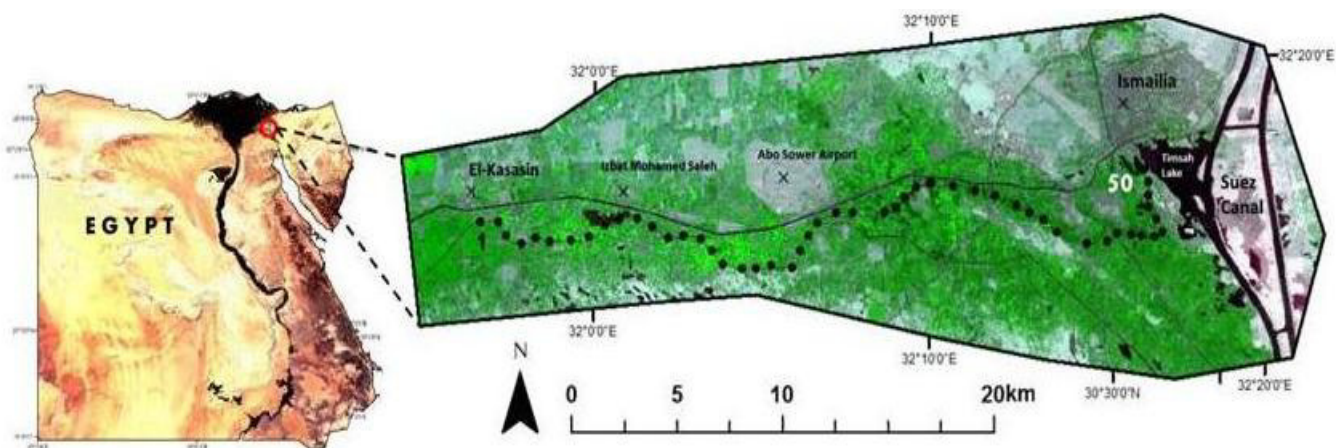
Fig. 1. The geographical location of El-Wadi drain stream, Ismaillia, Egypt. The points in the map represent the 50 sampling locations starting from the western to eastern side, true color composite (RGB) for a mosaic Sentinel-2 satellite image, and the datum is WGS 1984.

one sample every 1 km). Samples were taken in plastic bottles and prepare for chemical analyses. Major ions (cation and anion) can be used to evaluate the quality of water, as they represent the majority of dissolved species like calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), chloride (Cl^-), sulfate (SO_4^{2-}), carbonate (CO_3^{-2}), and bicarbonate (HCO_3^-). Other cations and anions may also be present, but their concentrations are generally lower than those of the major eight in water. Electrical conductivity (EC dSm^{-1}) was measured using conductivity meter model 710 (Richards, 1954). Na^+ and K^+ were determined flame photometerically, Ca^{2+}, Mg^{2+} with titration method using ethylene diamine tetra acetic acid (versinate), Cl^- with titration method using silver nitrate, HCO^{3-} with titration using standard sulphuric acid (Page et al.,1982). Sulfate anions (SO_4^{2-}) were precipitated by barium chloride as barium sulfate and gravimetrically determined (Jackson, 1973). Sodium adsorption ratio (SAR) and adjusted SAR (Adj SAR) were calculated as reported by Ayers and Westcot (1985). Adjusted sodium ratio (Adj.R_{Na}) was calculated as suggested by Suarez (1981). Residual sodium carbonate (RSC) was estimated as described by Richards (1954). Exchangeable sodium percentage (ESP) was estimated from the analytical data (Al-Othman, 2008).

Multi-element analysis including iron (Fe), copper (Cu) and nickel (Ni) and phenolic compounds were determined from all water samples using ion chromatography (ICS-5000) coupled by UV/VIS and electrochemical detectors for metals and phenols, respectively. Thermo scientific DionexIonPac CS5A analytical column and CG5AGuard Column were used for metal determinations where thermo scientific DionexIonPac NS1 analytical Column and IonPac NG1 Guard Column were used for phenol measurements. The values of all determinants are the average of three time analysis.

Remote sensing datasets and analysis

Datasets

The LULC and spatial distribution of the samples are based on Sentinel-2 multispectral satellite images, which is the second in Sentinel satellite family that has been launched by European Space Agency (ESA) with different spatial resolution (10, 20, and 60 meters). The satellite data were acquired in three dates (February 19th, August 3rd, and September 2nd, 2015). These dates must meet the image processing requirement such as clear atmospheric condition, no sand storms, different cultivation seasons, and the temporal window of the water sampling. The Sentinel-2 satellite images were obtained from the Earth Explorer web-based tool in the USGS Earth Resources Observation and Science (EROS).

Supervised classification

The maximum likelihood classification method was considered as one of the most common and accurate methods for image classification in environmental and land cover monitoring researches in arid and semi-arid regions (Badreldin and Goossens, 2013; Diouf and Lambin, 2001; Richards, 2013; Zhou et al., 2008). For accurate classification that represent the reality require several steps and conditions as follow: (1) identifying the visible information that can be represented in classes and categories, (2) the chosen classes must be recognized by satellite image and ground survey, (3) selecting the prototype pixels (training pixels) that represent each chosen class or category, and (4) running the pixel's signature class analysis will produce the presets classes that has certain bandwidth (nm). The Normalized
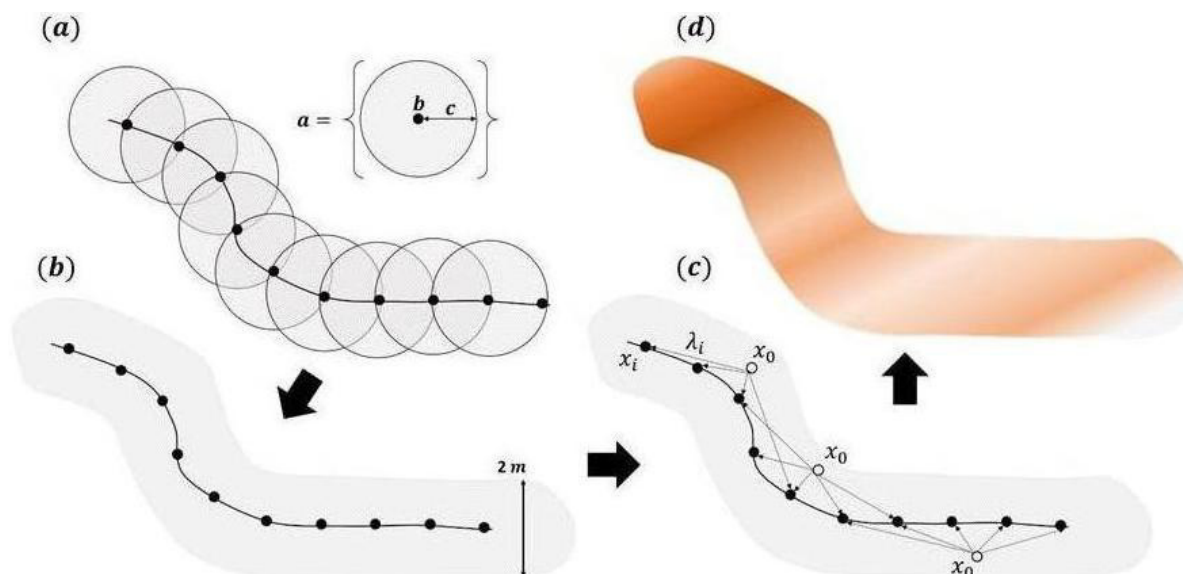
Fig. 2. Illustration draw for the buffer zoning, and the spatial interpolation window, (a) circles of buffer zones 'a' for each sampling point 'b' with a buffer radius of 1 km 'c'; (b) the spatial interpolation window with a width of 2 m; (c) the interpolation elements x_0 is the estimated point, x_i is the observation point, and λ_i is the weight (Eq. 2); and (d) the final presentation of spatial interpolation using the ordinary kriging (OK).

Difference Vegetation Index (NDVI) was used in the classification process in order to improve the producer's and user's accuracies.

$$NDVI = \frac{\rho_8 - \rho_4}{\rho_8 + \rho_4} \qquad (1)$$

Where ρ_8 is the reflectance value of the near infrared band that has central wavelength 842 nm, and ρ_4 is reflectance of the red band with central wavelength 665 nm, both bands have spatial resolution of 10 m.

Spatial interpolation

A buffer zone was created around the 50 observed samples to better understanding with the associated LULC classes with the interpolated ground surface, more specifically the spatial distributions of Cu, Fe, Ni, and phenols concentrations. This method is better to identify the source and the associated anthropological activities that cause contaminants distributions. As shown in Fig. 2a, each point was surrounded with a radius of 1 km that will be later the interpolation window (Fig. 2b), the distance and values between and for each observation point and each predicted point will calculated through different spatial interpolation models that is better to estimate the unknown surface (Fig. 2c, d). The water samples that represent Cu, Fe, Ni, and phenols are denoted as $z(x_1), z(x_2), \dots, z(x_n)$, where x_i is the location vector and n is the number of observations (n = 50) that were used for predicting the unallocated samples inside each grid in the buffer zone along the case study area using ordinary Kriging (OK) method (Badreldin et al., 2015; Webster and Oliver, 2007)

$$Z(x_0) = \sum_{i=1}^{m} \lambda_i z(x_i) \qquad (2)$$

Where, m is the number of neighbors in the merged buffer zones and λ_i are the weights.

Cross validation with 855 points was used to assess the accuracy of the interpolated information using root mean square error (RMSE), which deals with indicating how far the predictions from observations, and the second accuracy assessment is root mean square standardized error (RMSSE), which was used to show if the predictions were over or under estimated (Badreldin et al., 2015; Nawar et al., 2011; Webster and Oliver, 2007).

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{m} \{Z(x_0) - Z(x_i)\}^2} \qquad (3)$$

$$RMSSE = \sqrt{\frac{\sum_{i=1}^{m} \left\{ Z(x_0) - Z(x_i) \middle/ \sigma(x_i) \right\}^2}{n}} \qquad (4)$$

Where, $\sigma(x_i)$ is the estimated error variance and n is the sample size (n= 855)

As shown in Tab. 1, the cross-validation results of the OK model support the estimation process and the spatial interpolated surface.

RESULTS AND DISCUSSION

General chemical characteristics of tested water samples

pH, temperature, EC and TDS

Water pH, EC, temperature and TDS (total dissolved solids) were determined in water samples of fifty

Table 1. RMSE and RMSSE for Fe, Cu, Ni, and Phenol concentration ($\mu g\ l^{-1}$) validation based on cross validation (n=855).

	Fe	Cu	Ni	Phenol
RMSE	4.08	0.99	83.1	4.56
RMSSE	1.96	0.42	4.09	1.08

Table 2. Descriptive statistical analysis (mean, standard deviation; SD, minimum and maximum values) for various characteristics of water, (n = 50)

	Mean	SD	Minimum	Maximum
pH	7.20	0.14	6.79	7.51
Temp °C	17.1	0.99	15.3	18.2
EC dSm^{-1}	1.29	0.38	0.40	1.65
TDS mgL^{-1}	828	243	254	1059
NO$_3$mgL^{-1}	7.65	1.03	6.95	8.35
NO$_2$ mgL^{-1}	0.511	0.28	0.187	0.835
NH$_4$ mgL^{-1}	2.065	0.61	1.05	3..08

locations from El-Wadi drain, Ismaillia, Egypt (Tab. 2). It has been established that pH of the water is considered as one of the most significant water quality parameters in the aquatic system. In this study, the pH values in the studied samples were in the range from 6.79 to 7.51 with general average of 7.70 ± 0.14 (Table 1). The permissible limit of pH in irrigation water ranged from 6.0 to 8.4 (FAO, 1994). The results indicated that pH values are neutral and within the permissible limit. Thus, the pH of the drain was in the recommended range for irrigation. Average water temperature was 17.1± 0.99 °C; ranged from 15.3 to 18.2 °C, indicating moderate weather. Electrical conductivity (EC) values were ranged from 0.40 to 1.65 dSm^{-1} with an average value of 1.29±0.38 dSm^{-1} (Table1). A relatively wide range of water salinity may represent different sources of water input (ElKashouty et al., 2012). EC measures the ability of water to carry electrical current, where the EC degree of restriction on reuse is: none on< 0.70 dSm^{-1}; slight to moderate on 0.70 – 3.00 dSm^{-1}; severe on > 3.00 dSm^{-1} (Ayers and Westcot, 1985). The lowest value of EC was recorded in the beginning of El-Wadi drain (0.40dSm^{-1}) where, the water doesn't mix with other water drainage that passes through the soil. However, the high EC values were observed after 20 km from the begging of the drain. The higher values recorded for EC could be attributed to the enrichment of salts in the drain. These are probably due to the anthropogenic activities in the region and geological weathering conditions resulting in high concentrations of dissolved minerals (Dinka et al., 2015). High EC means high degree of salinity and an index of the amount of dissolved substances in water (Thompson et al., 2012). Therefore, all tested samples could be used for irrigation with none to moderately restriction on irrigation use in terms of salinity.

TDS, which is a measure of the degree of water quality, was 254–1059 mg l^{-1}with a mean value of 828 ± 243 mg l^{-1}. TDS values over 500 mg l^{-1} indicated the presence of slightly elevated salt concentration, and can be related to the other problems such as hardness (WHO, 1996b). Based on TDS measurements, the degree of restriction on reuse is: none on <450 mg l^{-1}; slight to moderate on 450– 2000 mg l^{-1}; severe on >2000 mg l^{-1} (Ayers and Westcot, 1985). However, some locations along the drain had slight to moderate restrictions on reuse for irrigation purposes. Also, NH$_4$, NO$_3$ and NO$_2$ values are less than allowed, so there is no problem ammonia, nitrates and nitrites. Recommended values for ammonia 2 - 75 mg l^{-1}, Nitrate from 5 to 50 mg l^{-1} and nitrite from 1.1 to 11.3 mg l^{-1}, water used without problem.

Soluble anions and cations

Evaluation of mean, median, maximum and minimum values of anions and cations are depicted in box plots (Fig. 3). The abundance of anions and cations was in the following order: Cl$^-$ > SO$_4^{2-}$ >HCO$_3^-$ and Na$^+$> Ca^{2+}> Mg^{2+}> K$^+$, respectively. The results showed that both Na$^+$ and Cl$^-$ (Fig. 3) were the highest values among all ions. They were in average of 169 ± 53.4 and 283 ±102 mgL^{-1}, respectively.

The boxplot shows the median (open symbol) and mean (closed symbol). Outliers represents as asterisk symbols.

Chloride ion usually exists in the form of chlorine salts (NaCl, CaCl$_2$ or MgCl$_2$) and is extremely soluble in water. Fig. 4 showed a significant correlation (p < 0.01) between Cl ions and Na (r = 0.92), Ca (r = 0.86) and Mg (r = 0.88), which may suggest the form of Cl-Ca/-Mg/-Na complexes in the drain water. Chloride also occurs due to industrial and municipal wastes and irrigated agricultural activities. The chloride concentration serves as an indicator of pollution by sewage (Kumar et al., 2007). The degree of restriction for reuse in surface irrigation based
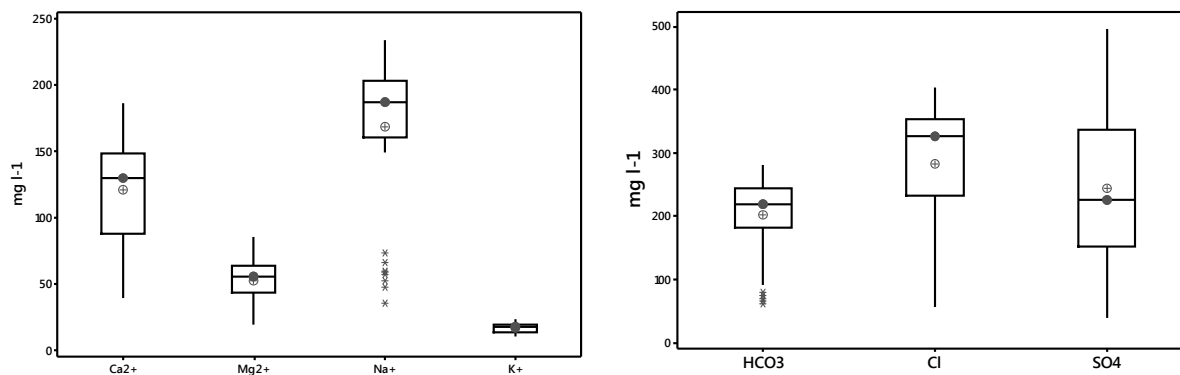
Fig. 3. The measured cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (HCO_3^-, Cl^- and SO_4^{2-}) for all water samples (n = 50).
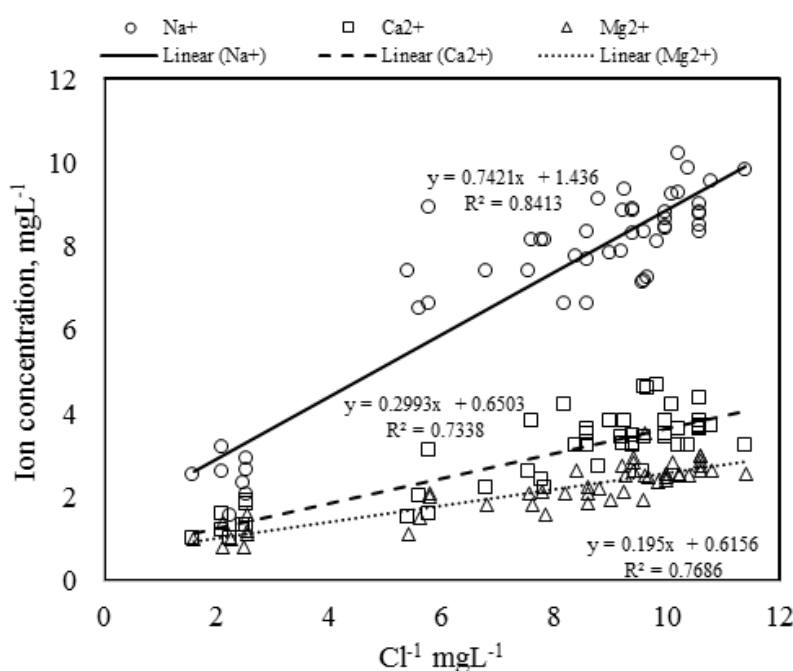

Fig. 4. Relationship between the concentration of Cl^- and Na^+, Ca^{+2}, Mg^{2+} (mg L^{-1}) in the water samples.

on Cl^-, is none on <142 mg l^{-1}, slight to moderate on 142–355 mg l^{-1} and severe on>355 mg l^{-1} (Ayers and Westcot, 1985). However, the Cl of the drain was in the allowable range for irrigation purposes. The much higher increase in the concentration of chloride and sodium relative to the concentration of calcium and magnesium reflects the very high levels of their existence in soils. At the same time, soluble cations and anions of the different water locations, increased progressively with increasing salinity content of the water. Sodium (Na^+) and Cl^- increased progressively with increasing salinity levels in the irrigation water; Person correlation between EC, Na and Cl were 0.96 (p < 0.01) and 0.97 (p <0.01), respectively. Similar results were obtained by Nikos et al. (2003) and Ahmed (2013). The authors reported that EC is good

estimator of the total amounts of mineral salts that dissolved in water.

Water quality parameters

To better understand the drainage quality for irrigation uses, several parameters have been examined to evaluate the tested water utilizing major cation measurements such as Na, Ca and Mg. These parameters included SAR, Adj SAR, AdjR$_{Na,}$ RSC and ESP.

The SAR parameter assesses the Na hazard in relation to soluble Ca and Mg (Shaki and Adeloye, 2006). Based on Na hazard, water has been classified into four
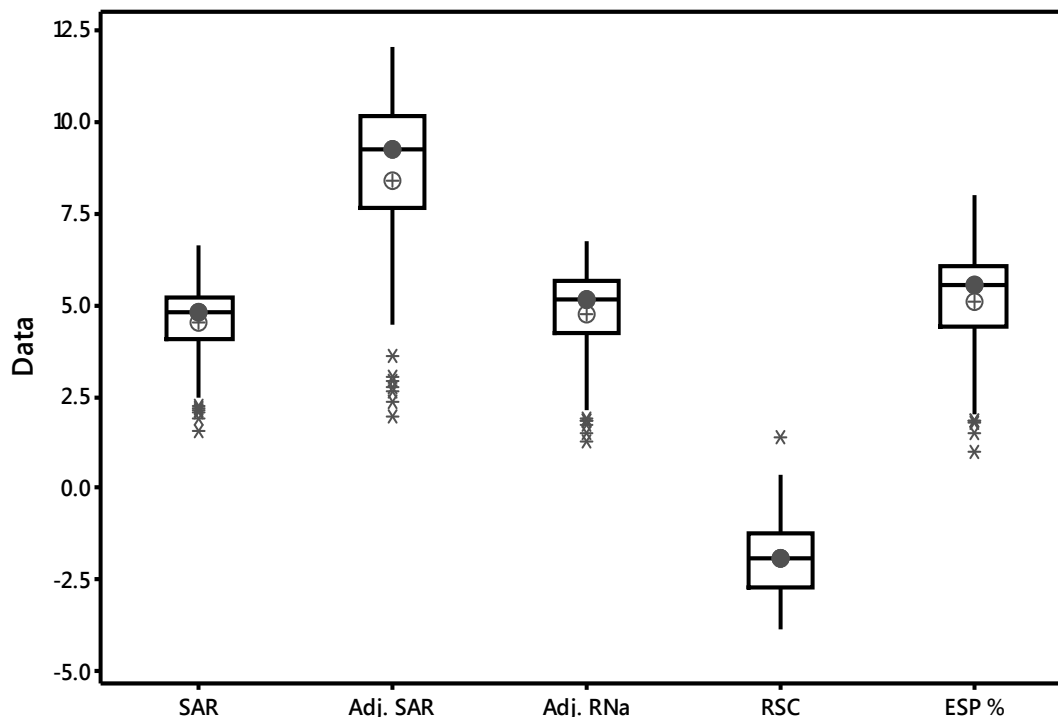
Fig. 5. SAR, Adj. SAR, Adj RNA, RSC and ESP % values estimated in water samples of El-Wadi drain stream. The 'Box and Whisker' plot shows the median (open symbol) and mean (closed symbol) for all estimated parameters. Outliers represents as asterisk symbols.

clusters including low (<10), medium (10-18), high (18-26) and very high (>26) types (USSL, 1954). When SAR values are lower than 10 (Sappa et al., 2015), the tested water sample considered safe and suitable for irrigation. However, according to Food and Agriculture Organization (FAO), the SAR values above 6 - 9, the irrigation water will cause permeability problems (FAO, 1992). Actually, the high SAR causes weakness in the soil physical structure (i.e. reduce hydraulic conductivity and aggregate stability and swelling of clays). Fig. 5 shewed that SAR (average ± SD) values of water samples, ranged from 1.56 to 6.64 (4.35 ± 1.20).Therefore, all samples show SAR values below 10 (Fig. 5) indicating their suitability for irrigation purposes (USSL, 1954). Although SAR and Adj SAR are similar to present Na hazard in the soil, Adj. SAR calculation takes into account the effects of carbonate and bicarbonate ion concentrations of soils. Adj. SAR is the most common method for determining sodium hazard in irrigation water at the present time. It is recommended that SAR be adjusted to include a more correct estimate of calcium in the soil water following irrigation. The $adjR_{Na}$ calculated by this product is to be substituted for the SAR value. Both values (Adj. SAR and $AdjR_{Na}$) show average of 8.42 ± 2.96 and 4.75 ± 1.43, respectively (Fig. 5). The comparison between SAR, adj SAR and $adjR_{Na}$ values and their standard values reflects water is suitable for irrigation.

The RSC has been calculated to determine the hazardous effect of carbonate and bicarbonate on the irrigation water quality. RSC ranges from –3.81 to 1.40 with average of -1.90 ± 1.08 (Fig. 5) indicating that most of the samples are suitable for irrigation where good quality water's RSC should be less than 1.25. Most of the RSC concentrations are minus (94% of total samples), and the continued usage of low RSC waters will not affect the yields of crop Li et al (2017a and 2017b). ESP values ranged from 1.02 to 8.02 with average of 5.13 ± 1.65.

The potential soil infiltration and permeability problems created from applications of irrigation cannot be adequately assessed on the basis of the SAR alone; therefore, the best measure of a water likely effect on soil permeability is the water SAR considered together with its EC. Therefore, the regression analysis showed (Fig. 6a) a strong relationship between EC and SARs (SAR; R^2= 0.58, Adj SAR; R^2= 0.77 and AdjRNa; R^2= 0.71). The US Salinity Laboratory (USSL) diagram (USSL, 1954) considers the alkalinity and salinity of irrigation water simultaneously. As shown in Fig. 6b, all the samples are plotted in C2S1 (18 % of the total samples) and C3S1 (76%), expect three samples in C3S2 indicating a good to acceptable quality for irrigation. The samples plotted in C3S2 (sample 11, 12 and 14 from western side of the sampling locations (Fig. 1) contains medium salinity and is suitable for irrigation considering sensitive plant to salinity.
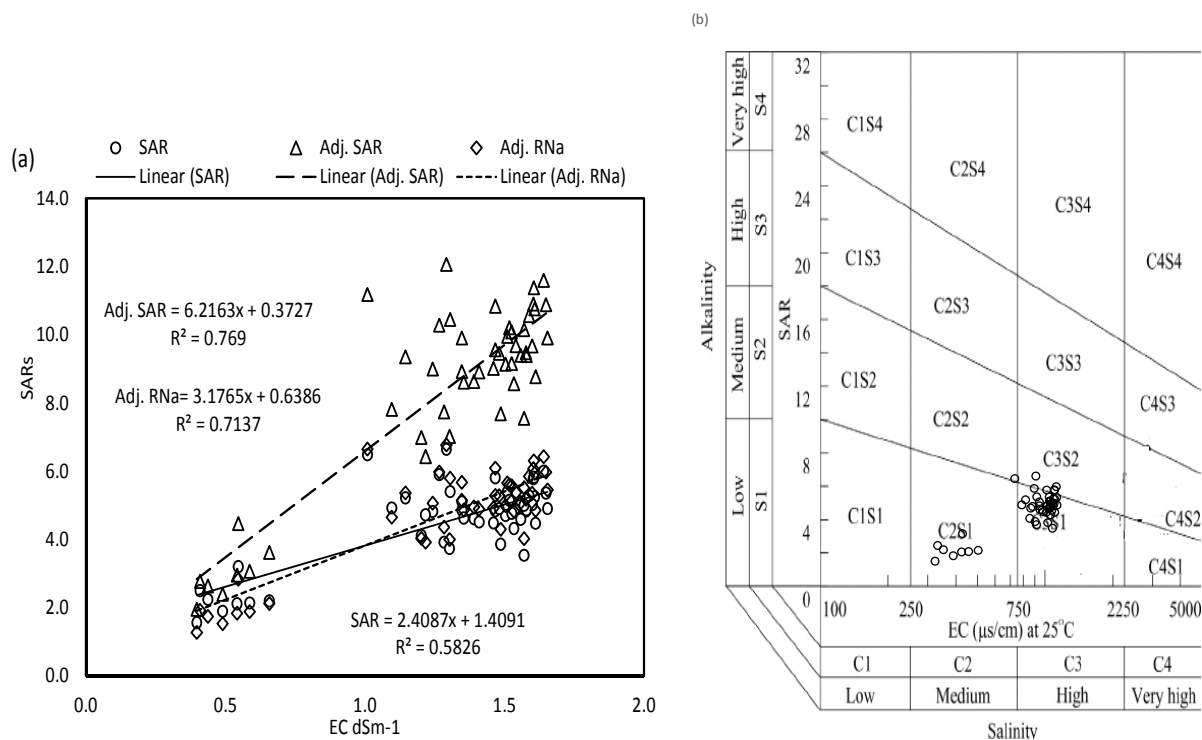
Fig. 6(a). Relationship between EC and SAR, Adj.SAR, Adj.R$_{Na}$; (b) The US Salinity Laboratory (USSL) diagram.
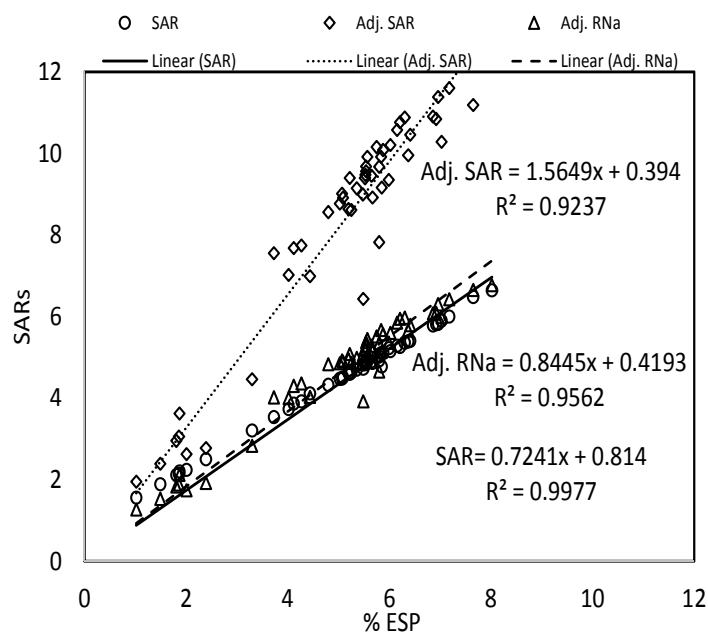

Fig. 7. Predicting ESP (%) of soil from SARs of the drainage water of El-Wadi drain stream.

The predicted ESP (Fig. 5) using drainage water for irrigation is presented in Fig. 7. The ESP values predicted from SAR and adj. R$_{Na}$ are much higher than those predicted from the adj SAR of drainage water. However, all predicted ESP values do not show any sodicity hazards upon irrigation with drainage water

because the upper safe limit of ESP value for soil is 15 according to USSL, (1954), hence, there is no immediate concern of soil sodicity problem from drainage water irrigation.

Trace metals and phenolic compounds

Trace elements occur in almost all water supplies but at very low concentrations. They are not often included in a routine analysis. As a result of reuse drainage water for irrigation, there is a need to quantify trace metals and other contaminants that may affect soil health, plant growth. However, not all trace elements are toxic and in small quantities many are essential for plant growth (Fe, Mn, Mo, Zn). However, excessive quantities will cause undesirable accumulation in plant tissue and growth reductions. In this concern multi elements were measured in all samples but only three of them were detectable (Fe, Cu and Ni).

Iron (Fe) and copper (Cu) are essential nutrients required in trace amounts for plant growth as well as human and animal health. For maintaining the life processes in plants and/or animals including humans these elements are necessary and therefore are essential micronutrients. Nickel (Ni) found in plants is not essential nutrients as such, but animals have developed a dependency on this element for use in their metabolic processes.

Trace elements enter an agro ecosystem through both natural and anthropogenic processes. In many cases, either toxicity or deficiency may be inherited from parent materials (Henry et al., 2004). Conversely, enrichment with trace elements may arise through the application of inorganic fertilizers, organic manures, pesticides, industrial and municipal wastes and other anthropogenic sources. Therefore, measuring trace metals in drainage water is required because in the long term application, the use of such water may represents both a risk of toxicity or a potential benefit in terms of nutritional application to arable soils.

To better understand the relation between heavy metals and phenol compounds and LULC, the spatial distribution of LULC classes along with Fe, Cu, Ni and phenol concentrations was undertaken as shown in Fig. 8. Initially, the LULC map for the entire case study, water bodies: including water ponds, artificial and natural canals, and drainage streams (Fig. 8a); Urban area including cities, counties, airport, bare soil, and industrial territories; Poorly Cultivated Area (PCA) including location that are cultivated once a year with annual plants and/or degraded agriculture area; Moderately Cultivated Area (MCA) including location that are cultivated more than once a year with annual plants; and Intensively Cultivated Area (ICA) including locations that have permanent trees with constant vegetation cover.

The average values (with a range level) for measured elements were 52.0 ± 46.5 μl^{-1} $(0.23 - 196$ μl$^{-1})$ for Fe, 7.01 ± 6.45 μl^{-1} $(0.00 - 21.2$ μl$^{-1})$ for Cu and 366 ± 675 μl^{-1} $(1.20 - 3140$ μl$^{-1})$ for Ni (Fig. 8). Both Fe (Fig. 8a) and Cu (Fig. 8c) are within the permissible limits of irrigation water according to FAO (1992) (Fe = 5000 μl^{-1} and Cu = 200 μl^{-1}) while 20% of the total samples are upper the permissible limit for Ni (200 μl^{-1} (Fig. 8d).

The western side of the case study contains high concentrations of heavy metal concentrations. The highest concentration of Fe ($\sim 195 \mu g\ l^{-1}$) was found in 27 km away from the fist sample (Fig. 8b). This location is associated with high cultivation activity (Fig. 9a), high concentrations of Cu and Ni($\sim$ 20 and $3150 \mu g\ l^{-1}$, respectively) were found in the first 5 km in the western side of the case study (Fig. 8c and d). Copper was found highly associated with MCA and PCA as a result of intensive agriculture management of soil manures and land reclamations (Fig. 9).

These samples exist from the beginning of the drain eastward had a huge amount of Ni compared to FAO standards and ranged from 276 to 3140 μ Ni l^{-1} (10 samples). Taking into account short and long term use of El-Wadi drain water, Australian guidelines contaminant concentrations of Ni in irrigation water are 2000 μL^{-1} for short-term use (20 years) and 200 μL^{-1} for long-term (100 years) use (McLaughlin et al., 2001). Results of the present investigation emphasize the necessity of accurate long term monitoring for Ni levels in El-Wadi drain. The existence of some small factories working in paints, scrap yards and heavy residential area with ICA and MCA in the first 20 km of the drain might also explain the high level of Ni concentrations in these locations. Nickel has been used in many processes such as electroplating, leather tanning, wood preservation, pulp processing, steel manufacturing, plastics pigments, mining and metallurgical processes then discharged into the environment (Aksu and Dönmez, 2003; Gupta et al., 2010). More serious precautions should be considered for reusing the drain water in the MCA and ICA due to high level of Ni (location No. 9, 10, 11, 13, 15, 17, 19 and 20; Fig. 9).

Phenolic compounds as organic pollutants are gaining great popularity due to their widespread application to produce pharmaceutical fragrance, polymeric materials, dyes, paper, pesticides and petrochemical products etc. Therefore, it is not difficult to understand their presence in the drainage waters. Due to its toxicity, they could have significant detrimental effects on water quality or animals as well as some plants even at very low level. For these reasons, some of them have been included in the lists of priority pollutants (Hossain and Salehuddin, 2009). Fig. 8e shows that phenols (as a total compounds) ranged from 34.8 to 146 μgl^{-1} with an average of 82.9 ± 32.1 μgl^{-1}. The phenolic compounds were highly concentrated in the last 40 km eastern side of the case study ($\sim 150 \mu g\ l^{-1}$) (Fig. 8e,). The high phenol concentrations were associated more with urban
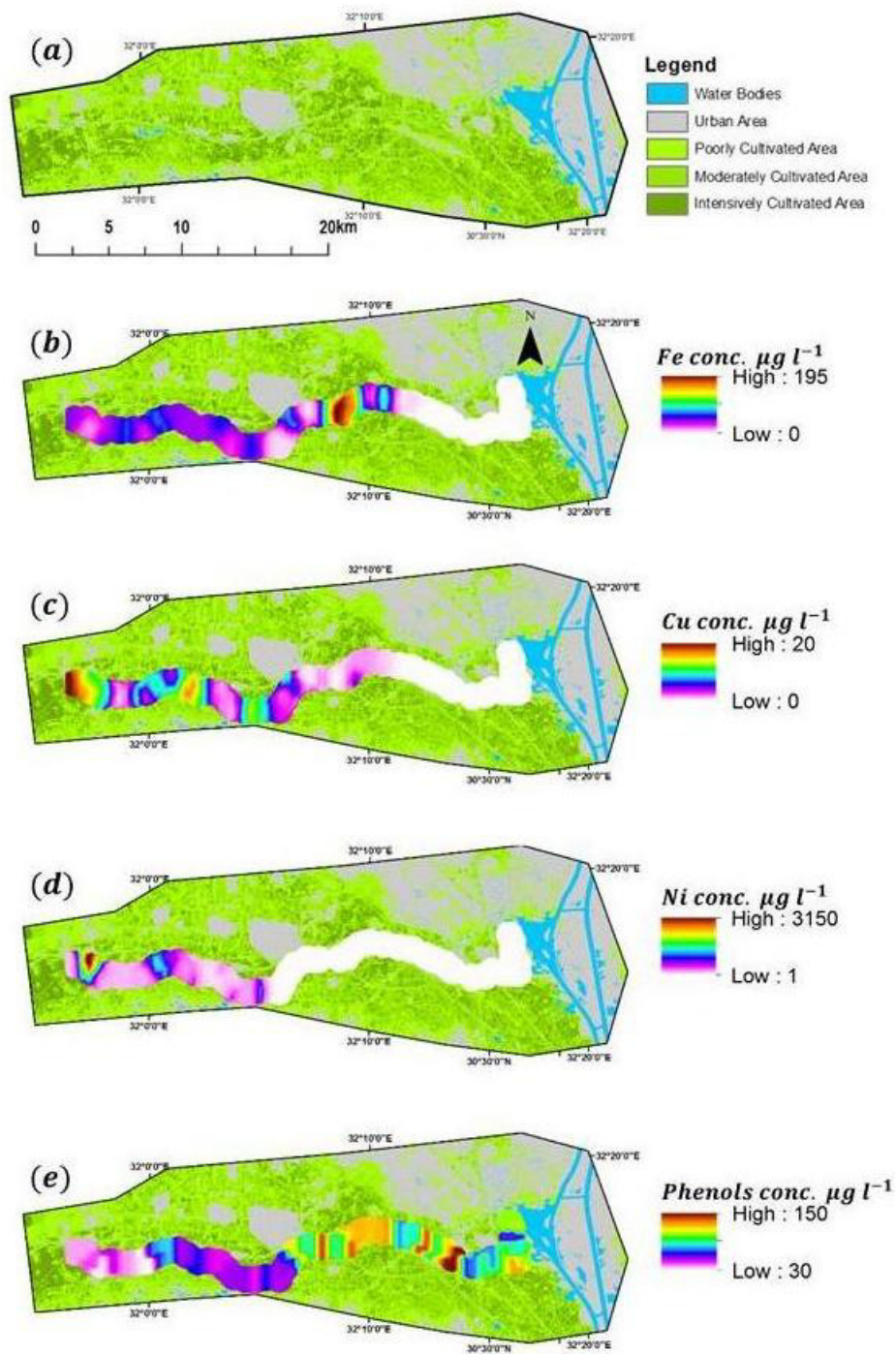
Fig. 8. The LULC map (a) along with interpolated samples for followings: (b) Fe; (c) Cu: (d) Ni; and (e) phenol concentrations in ($\mu g\ l^{-1}$).
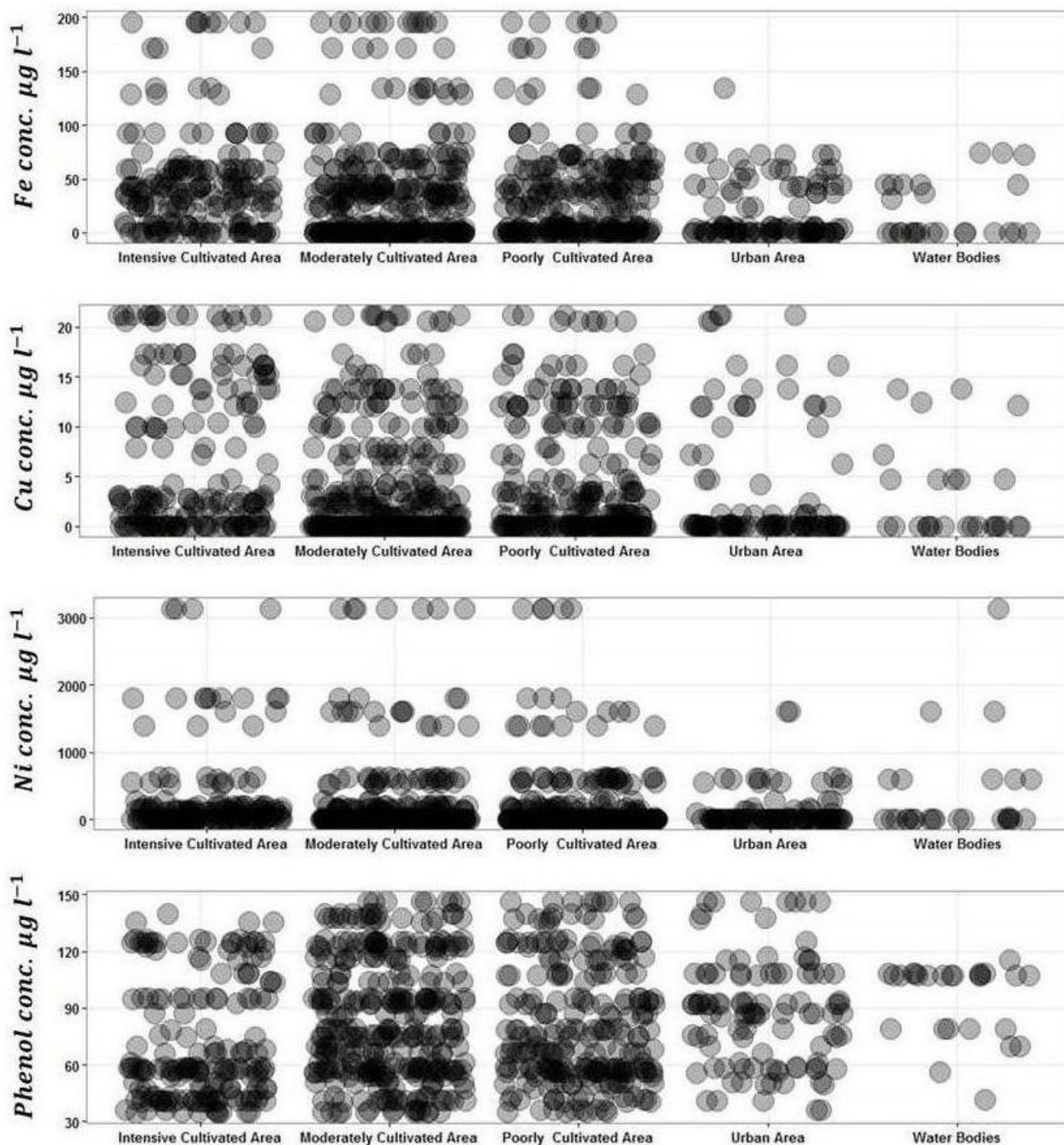
Fig. 9. The concentrations of Fe, Cu, Ni, phenol in ($\mu g\ l^{-1}$) over five different LULC classes, n=175 for Intensive Cultivated Area; n=315 for Moderately Cultivated Area; n= 238 for Poorly Cultivated Area; n= 102 for Urban Area; and n= 26 for Water Bodies.

area, MCA and PCA (Fig. 9). This concentration might be also attributed from some untreated olive mill wastewater disposed directly to the drain by the small oil extractor that exists alongside the drain. It has been established that olive mill wastewater had elevated concentration of phenolic compounds, which have toxic properties (Mekki

et al., 2013). Therefore, according to permissible limits of total phenol concentration (20 µgl⁻¹) established by Egyptian legislation (Egyptian Code 501, 2005) for irrigation water, this water is not suitable for irrigation; especially, for vegetables and fruits. Therefore, many associated health problems are expected as a

result of consuming the edible parts of plants irrigated with these drainage water (Salem et al., 2016). The results indicated the correlation of total phenols as one of the water pollution indicator

CONCLUSION

Although, conventional water quality measurements have been extensively used to assess water for irrigation uses, there is a potential risk of other organic and inorganic contaminants. Therefore, in this context, heavy metals and phenol compounds were measured along with water quality parameters of El-Wadi drain stream. Depending on water quality parameter and soluble cations and anions, drainage water was almost suitable for irrigation purposes. The US salinity diagram showed 93 % of the water samples were acceptable for irrigation while the rest of samples could be used for irrigation taking into account a sensitive plant for salinity. However, organic pollutants (phenols) in water recorded high concentration values than the Egyptian permissible limits, while inorganic elements were within the safe limits for irrigation with exception of Ni in the intensive and moderate cultivated areas. The highly polluted locations were associated with intensive cultivated areas reflecting human activities. To avoid both organic and inorganic, it is recommended that small olive oil extractors and other anthropogenic activities located alongside the drain should be relocated in remote areas with precaution of treating their effluents. Therefore, organic and inorganic pollutants should be included in routine analysis work for evaluating drainage water for irrigation.

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