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SUBMISSION ADDRESS:

Professor **Eid A. Al-Tarazi**
Deanship of Academic Research and Higher Studies
Hashemite University, P.O. Box 150458, Postal Code 13115, Zarqa, Jordan.
Phone: +962-5-3903333 ext.4229
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Deriving the Pore Structure of Selected Jordanian Building Limestones

Basem K. Moh'd*

Civil Engineering Department, Tafila Technical University, Jordan

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Abstract

Making water absorption as the independent variable in the equations of Moh'd and Cranganu (2012), we have used these equations to predict the pore structure (porosity, pore size distribution, seepage radius, specific surface area, tortuosity and permeability) of 12 clean Jordanian building limestones. In the present work, first, the stones were subdivided into unimodal and bimodal pore networks (by plotting their porosity against the bulk volume water or modified saturation). Then, the 24-hour water absorption was used to derive the pore structure of unimodal and bimodal porosity limestone. The two chalky samples (Izrit and Hatem) stones gave anomalous results. This can be explained by the fact that the original Russian database, which the present work is based upon, did not include any chalky samples. The results are not thus recommended to be extended to the to chalky limestones; it is however recommended that a similar research be carried out employing a representative number of chalk samples for deriving the pore structure of chalk from water absorption.

Keywords: pore structure, tortuosity, surface area, permeability, water absorption, Jordanian building limestone.

1. Introduction

Although it is known that water behavior in limestone is a function of limestone's pore structure which is largely controlled by the texture of the rock and also despite the fact that water absorption (amount and/or rate) measurement is required for most building material (stone, aggregate and concrete) standards, very little work has been done to quantify the water absorption-pore structure relationship (Coskun and Wardlaw, 1995; Winslow, 1987).

Pore structure characterization (amount, size, shape, connectivity and distribution) characterization in carbonaterocks is important in many applications related to oil industry (Dullien, 1979; Asquith, 1985; Jordy, 1992; Chillingarian et al., 1992) and to ground water aquifer exploitation and pollution (Cander, 1995). As many industrial applications of limestone are controlled by purity, grain size and internal surface area they may directly or indirectly be influenced by pore structure (Hartman and Coughlin, 1974). In limestone and dolomite, metallic ore deposits are usually present in both primary and secondary pore types (Anderson and Macqueen, 1982).

In civil engineering, suitability of carbonate rocks as building materials (building stone, aggregate and concrete and asphalt mixes) and their frost- and salt-durability are largely controlled by their pore structure (Leary, 1983; Cnudde et al., 2009). Knowledge of pore structure is critical for the success of restoration of historic buildings and archeological sites (Ashurst and Dimes, 1990).

It is well-known that the amount of water absorption depends on porosity and the presence of absorptive mineral species such as clay minerals.

Moh'd and Cranganu (2012) investigated the water absorption in limestone as a new tool for pore space characterization. They used a small Russian database of clean limestone and dolostone to relate, using cross-plotting and multiple regression analysis methods, the rate of water absorption to pore structure parameters in unimodal and bimodal pore networks. Relationships have been established between porosity and pore size distribution, seepage radius, specific surface area, tortuosity and permeability with water absorption. These researchers found that most of the petrophysical properties can be easily derived from the amount of 24 hour water absorption. However, porosity and bulk volume water or modified saturation (= porosity * saturation) need also to be known or estimated so as to define the uni- or bi-modality of the pore space. Thus, a new and simple method is proposed to derive approximate values of most petrophysical properties using weight difference after submerging a carbonate sample in water for 24 hours. Porosity can be measured or derived from density. Pore network uni- or bimodality was found to have a stronger effect on the petrophysical properties than carbonate lithology type.

In clean carbonates, either capillary imbibition or total immersion causes the water sorption of porous material under natural conditions. The water sorption from total immersion can be considered as a generalized capillary sorption of all rock material surfaces (Bellanger et al., 1993).

The ratio between the natural capacity of a rock to absorb water and its absolute porosity is termed as saturation coefficient (Hirschwald, 1912); this principle has been

* Corresponding author. e-mail: basemkm@yahoo.com

introduced in connection with frost damage caused by the 10% expansion that occurs on freezing.

In the present work, it is intended to derive the pore structure of selected Jordanian building limestones using database of Moh'd and Cranganu and the 24-hour water absorption as an independent variable after dividing their pore structure into unimodal or bimodal porosity types. Pore structure elements that are derived include: pore size distribution, seepage radius, specific surface area, permeability, and tortuosity. 12 Jordanian building limestones are studied including: Izrit, Hatem, Ishtafina, Yanabi, Hallabat, Tafih, Sahrawi, Mafraq, Jazeira, Sat'h, and Siwaqa and Mujeb travertine.

2. Methods and Materials

Water absorption, porosity and water saturation of the studied samples were measured at the laboratories of the QMW (University of London) and Building Research Establishment (BRE) in the United Kingdom (Moh'd, 1996). They were also employed in other publications of the author (Moh'd, 2002; 2007; 2008).

To subdivide the suite of the studied samples into those of unimodal and bimodal pore networks, porosity was plotted against modified saturation (Bellanger et al., 1993) (Figure 1). The following properties were multiplied by porosity to get an idea about the bulk volume water after a 24-hour saturation (modified 24 hour saturation), and pore size percentage less than 0.2 µm (modified less) and more than 0.2 µm (modified more). According to Moh'd (1996), most saturation takes place during the first hour of soaking. Thus, the 24-hour absorption was considered here to be roughly equivalent to saturation after 16 hours (used in the Russian database).

The following definitions of terms are used:

- Water absorption %: the weight of water absorbed by the rock after 24 hours of immersion in water divided by its oven-dried weight expressed as a percentage of its oven-dried weight.
- Modified water absorption: water absorption multiplied by porosity.
- Porosity%: the percentage of volume of voids over the total volume of rock.
- Saturation %: the percentage of pore volume, which can be filled with water after immersion in water for 24 hours.
- Modified saturation (msat): is saturation multiplied by porosity.
- Effective porosity % (effecpor): indicates interconnected pores and is the product of water absorption and dry density.
- More than 0.0002 mm pore diameters (more): percentage of this pore size portion.
- Modified more than 0.0002 mm pore diameters (mm): percentage of this pore size portion multiplied by porosity.
- Less than 0.0002 mm pore diameters (less): percentage of this pore size portion
- Modified less than 0.0002 mm pore diameters (ml): percentage of this pore size portion multiplied by porosity.
- Tortuosity (tort): the ratio of total path covered by an electric current flowing in the pore channels between two electrodes to the straight-line distance between the electrodes.
- Permeability (perm): in millidarcies, the ease with which fluids pass through the rock.
- Specific surface area (ssa): surface attributed to tortuosity (m^2/g).
- Seepage radius (seep rad): the radius of pore channel in µm.

The following equations have been derived from the original Russian database to derive the pore structure of Jordanian limestones:

For limestones with unimodal porosity:

Modified more = 0.3357* modified saturation$^{1.4453}$	$r^2 = 0.87$
Modified less = 0.0497* modified saturation + 0.9588	$r^2 = 0.95$
Tortuosity = 9.6416/ modified saturation$^{0.3902}$	$r^2 = 0.90$
Permeability = 6 E-7* modified saturation$^{5.5998}$	$r^2 = 0.90$
Specific surface area = 0.59938 Ln modified saturation + 18.243	$r^2 = 0.86$
Seepage radius = 0.2156 e$^{0.2958\ \text{modified saturation}}$	$r^2 = 0.93$

For limestones with bimodal porosity:

Modified more = 2.293* modified saturation + 0.1807	$r^2 = 0.97$
Modified less = - 0.1292 modified saturation + 1.5451	$r^2 = 0.99$
Tortuosity = -0.664 modified saturation + 12.506	$r^2 = 0.68$
Permeability = 0.0001 modified saturation$^{4.4167}$	
Specific surface area = - 2.3865 Ln modified saturation + 6.8761	$r^2 = 0.80$
Seepage radius = 0.7217 modified saturation$^{1.6747}$	$r^2 = 0.93$

3. Results and Discussion

Using the above-mentioned equations, the results of the pore structure elements calculations are summarized in Tables 1 and 2 along with correlation matrices between the different variables in both the uni- and bimodal porosity types.

Table 1. Derived pore structure elements and correlation matrix in rocks with unimodal pores

	Porosity	Saturation	msat	effecpor	more	mm	less	ml	tort	perm	ssa	Seep r
Ballas 9	1.92	0.75	1.44	1.46	0.296	0.5687	0.536	1.03	8.36	4.62E-06	18.02	0.33
Yanabi 10	1.52	0.80	1.216	1.214	0.293	0.4453	0.671	1.02	8.93	1.79E-06	18.13	0.31
Karak 9	1.79	0.75	1.34	1.224	0.286	0.5124	0.575	1.03	8.60	3.09E-06	18.07	0.32
Hayyan 10	5.76	0.75	4.32	4.459	0.483	2.7825	0.203	1.17	5.45	2.17E-03	17.37	0.77
Izrit 9	27.72	0.84	23.29	23.56	1.146	31.766	0.076	2.12	2.82	27.18	16.35	211
Hatem 10	20.87	0.78	16.28	16.02	0.907	18.9302	0.085	1.77	3.25	3.66	16.57	27

Table 1 continued

	Porosity	Saturation	msat	effecpor	more	mm	less	ml	tort	perm	ssa	seep rad
Porosity	1.00											
Saturation	0.72	1.00										
msat	1.00	0.74	1.00									
effecpor	1.00	0.75	1.00	1.00								
more	1.00	0.71	1.00	1.00	1.00							
mm	0.99	0.78	1.00	1.00	0.99	1.00						
less	-0.86	-0.37	-0.85	-0.85	-0.89	-0.81	1.00					
ml	1.00	0.74	1.00	1.00	1.00	1.00	-0.85	1.00				
tort	-0.94	-0.52	-0.93	-0.93	-0.95	-0.89	0.98	-0.93	1.00			
perm	0.84	0.84	0.86	0.87	0.84	0.90	-0.60	0.87	-0.69	1.00		
ssa	-0.97	-0.59	-0.96	-0.96	-0.98	-0.94	0.96	-0.96	0.99	-0.74	1.00	
seep rad	0.84	0.84	0.86	0.87	0.84	0.90	-0.59	0.86	-0.68	1.00	-0.74	1.00

Table 2. Derived pore structure elements and correlation matrix in rocks with bimodal pores.

	Porosity	Saturation	msat	effecpor	more	mm	less	ml	tort	perm	ssa	Seep r
Hallabat 10	14.32	0.59	8.449	9.279	1.365	19.55	0.031	0.45	6.89	1.24	1.78	25.73
Tafih 10	17.2	0.56	9.632	9.59	1.295	22.27	0.018	0.31	6.11	2.22	1.47	32.05
Travert 2	1.34	0.54	0.723	0.563	1.373	1.84	1.082	1.45	12.02	2.39E-05	7.65	0.42
Ma'an a 10	4.66	0.49	2.283	1.57	1.163	5.42	0.268	1.25	10.99	3.83E-03	4.91	2.88
Ma'an b 9	3.74	0.35	1.309	1.61	0.850	3.18	0.369	1.38	11.64	3.28E-04	6.23	1.13
Sahrawi 10	13.72	0.60	8.232	7.68	1.388	19.04	0.035	0.48	7.04	1.11	1.85	1.52

Table 2 continued

	Porosity	Saturation	msat	effecpor	more	mm	less	ml	tort	perm	ssa	seep rad
Porosity	1.00											
Saturation	0.63	1.00										
msat	1.00	0.69	1.00									
effecpor	0.99	0.66	0.99	1.00								
more	0.46	0.97	0.53	0.50	1.00							
mm	1.00	0.69	1.00	0.99	0.53	1.00						
less	-0.82	-0.24	-0.79	-0.78	-0.02	-0.79	1.00					
ml	-1.00	-0.70	-1.00	-0.99	-0.53	-1.00	0.79	1.00				
tort	-1.00	-0.69	-1.00	-0.99	-0.53	-1.00	0.79	1.00	1.00			
perm	0.96	0.60	0.94	0.94	0.47	0.94	-0.67	-0.94	-0.94	1.00		
ssa	-0.98	-0.62	-0.98	-0.96	-0.43	-0.98	0.90	0.98	0.98	-0.88	1.00	
seep rad	0.78	0.43	0.76	0.80	0.31	0.76	-0.55	-0.76	-0.76	0.86	-0.71	1.00

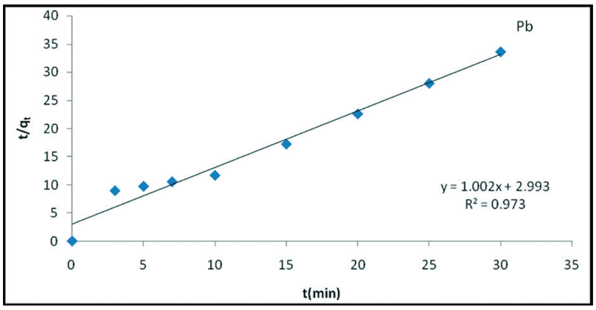

Figure 1. Unimodal porosity (blue points) fit with a straight line below which (pink points) bimodal porosity lies

Very few studies have been done previously on Jordanian stones apart from the work published by the present author (Moh'd, 2002; 2007; 2008) and by Ahmad (2011). As it can be seen from the very high correlation coefficients in both the uni- and bimodal porosity building stones of Jordan, most pore structure elements can be derived from porosity.

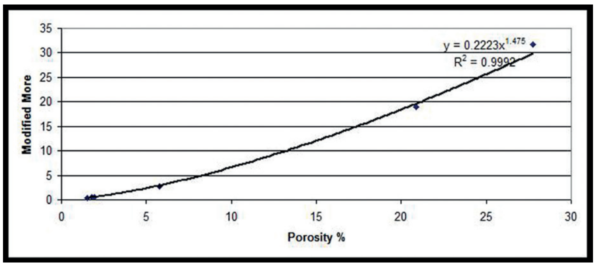

Figure 2. Porosity versus modified more in unimodal pore networks

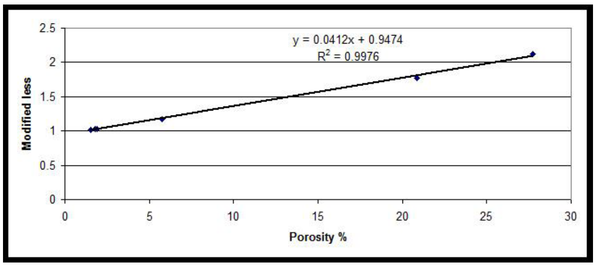

Figure 3. Porosity versus modified less unimodal pore networks

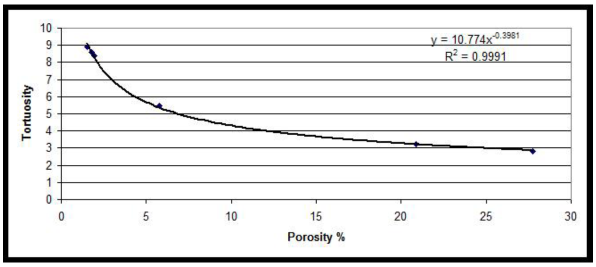

Figure 4. Porosity versus tortuosity unimodal pore networks

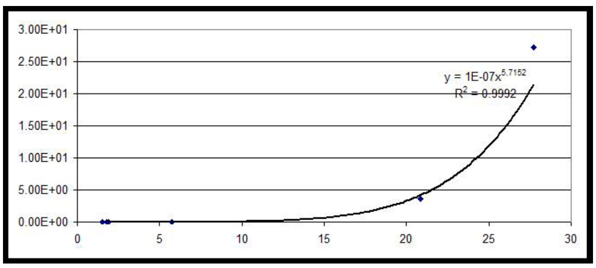

Figure 5. Porosity versus permeability unimodal pore networks

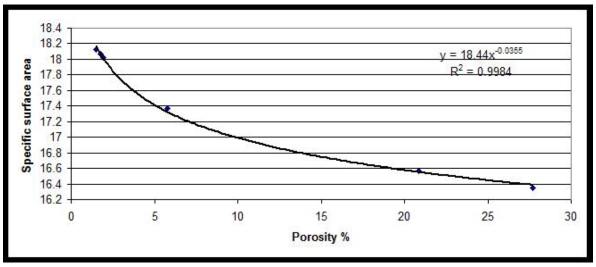

Figure 6. Porosity versus specific surface area in unimodal pore networks

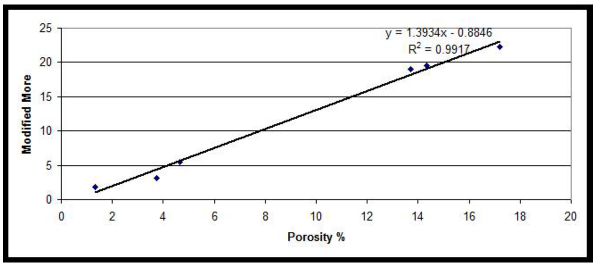

Figure 7. Porosity versus modified more in bimodal pore networks

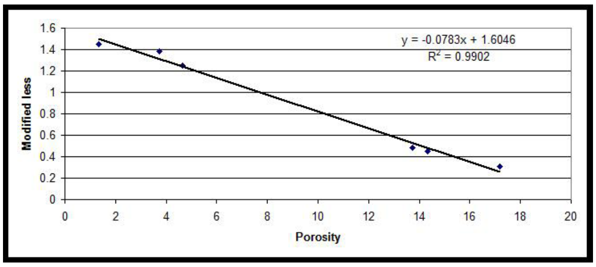

Figure 8. Porosity versus modified less in bimodal pore networks

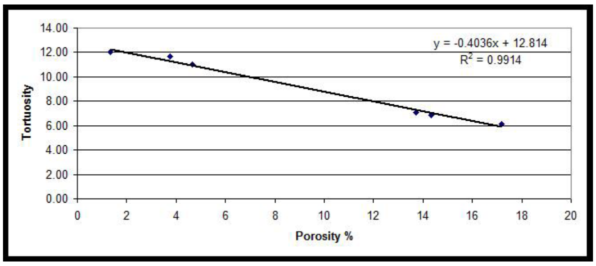

Figure 9. Porosity versus tortuosity in bimodal pore networks

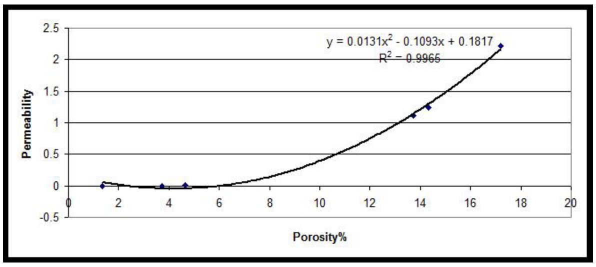

Figure 10. Porosity versus permeability in bimodal pore networks

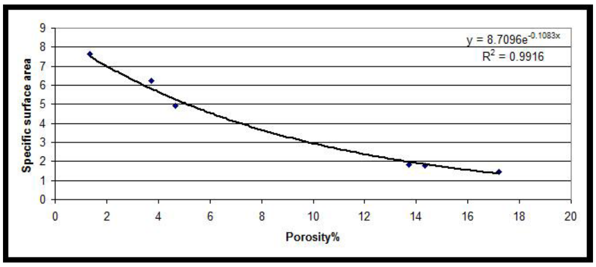

Figure 11. Porosity versus specific surface area in bimodal pore networks

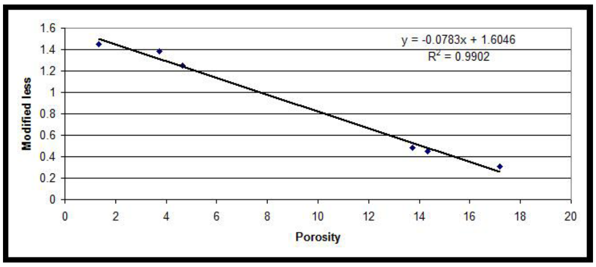

Figure 12. Porosity versus seepage radius in bimodal pore networks; one bad point was ignored

The two chalky samples (Izrit and Hatem stones) gave anomalous results of seepage radius. This can be explained by the fact that the original Russian database, which the present work is based upon, did not include any chalky samples. Using mercury intrusion porosimetry, Price et al. (1976) measured median pore diameters of the UK chalks ranging from 0.39 to 0.65 µm and 0.22 µm in marly chalk. Similarly, Bellanger et al. (1993) reported 0.4 µm for pore throats of French Jurassic chalk.

3. Conclusions and Recommendations

Most of the elements of pore structure of Jordanian building limestones were derived from the 24-hour water absorption values using 12 equations derived from the original Russian database. Modified saturation is the independent variable in these equations with very high correlation coefficients in both rocks with unimodal pore networks and those with bimodal porous networks. The difference between the present work and that carried by the present author in 2012 was that in the equations of the later work the 24-hour absorption was considered as the dependant variable.

Most pore structure elements can be derived directly from porosity (Figures 1-12). The two chalky samples (Izrit and Hatem stones) with unimodal porosity gave anomalous results concerning their seepage radii. This can be explained by the fact that the original Russian database, which the present work is based upon, did not include any chalky samples. It is thus recommended that the results not be extended to chalky limestones and to carry out a similar research employing a representative number of chalk samples to derive the pore structure of chalk from water absorption.

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Environmental Pollution of Cell-Phone Towers: Detection and Analysis Using Geographic Information System

M-Ali H. Al-Akhras[1, *], Borhan A. Albiss[1], Moath S. Alqudah[1], Taleb S. Odeh[2]

[1]*Bio-Medical physics laboratory, Jordan University of Science and Technology, Jordan*
[2] *Academy of Arid Lands, Hashemite University, Jordan*

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Abstract

Recent studies on environmental pollution from cell-phone towers have prompted a serious concern about their radiation hazards. Investigations in the present project are based on mapping the Electromagnetic Field (EMF) radiation levels in various locations in the north Jordan, which was shown to be highly radiated due to large number of cell-phone towers distributed throughout the region. Radiations comiung out of these towers were measured using spectrum analyzer, power strength meter and Geographic Position System (GPS). The present study focused on EMF radiation intensity measurement in crowded residential areas and public buildings and facilitated using far-field equation. The data of EMF radiation in the selected regions were processed and represented by digital map (2D and 3D) with interpolated using ArcGIS 9.3 software. Modeling and statistical analysis of the obtained results was compared with the international standards. In addition, this study demonstrated that both spatial and temporal factors contribute to residential EMF exposure and GIS technologies can be used to improve EMF exposure assessment and to guide the decision makers in Jordan to take serious and solid steps toward reducing radiation exposure limits and thus reducing health risks as much as possible.

Keywords: EMF Radiation, GIS Mapping, Spectral Analysis, Power Density.

1. Introduction

In the last few years, ElectroMagnetic Frequency (EMF) exposure effects on environmental pollution have been extensively studied worldwide. With the drastic increase of wireless electromagnetic radiation exposure, contradictory experimental proofs have been reported. Research studies on health risks, due to EMF radiation from cell-phone, cell-towers and base stations are still contradictory (Sharma, 2004). All over the world, people have been debating about associated health risk due to radiation from cell phone and cell towers. Recent studies on the (EMF) radiation from cell-phone towers have prompted serious concern about their radiation hazards. Several radiation effects of non-thermal has been reported (Singh and Kumar, 2012; AL-Akhras et al., 2001; Elbetieha et al., 2002; Saadet et al., 2012; Hashish et al., 2007; Usman et al., 2011; AL-Akhras et al., 2006, 2008a, 2008b; AL-Akhras et al., 2007a, 2007b; Aitken et al., 2005). Reports on exposure to electromagnetic radiation of 900 MHz from mobile phones showed that it could induce lipid peroxidation in human erythrocytes (Moustafa et al., 2001), in female and male rabbits (Güler et al., 2012) and in the hippocampus and brain cortex of rats as well as oxidative stress and histopathological changes in the rats' endometrium (Ilhan et al., 2004; Ferrari, 2012), induces a transient alteration of epidermal homoeostasis (Simon et al., 2012), effects which were reversed by antioxidants (Koylü et al., 2006; Guney et al., 2007). However, very few studies have been specifically focused on environmental pollution from cell- phone towers radiations, especially for people who live in crowded residential areas nearby the base stations or cell-phone towers. Recently, awareness about the effect of EMF radiation on human life is notably increasing. There are now growing claims (scientific, medical and public) that living close to power lines has a harmful health and environmental effects on human life (Sharma, 2004; Durduran et al., 2010; Moraru and Marica, 2011). Mapping and monitoring EMF radiation levels are still considered to be in its early stage. In this regard, more studies are needed using a highly sensitive measurement and mapping system for better understanding and minimizing the risk factors related to human health and environment. GIS and Global Positioning System (GPS) are known to be the most reliable method is used to identify and locate the various sources of EMF radiation. GIS is a scientific tool, involving the use of particular software, associated with hardware tools and digital geographic data in order to advance some specific scientific research objectives. These modern techniques have been applied to many applications to provide accurate positioning, data capturing, storing, analyzing, retrieving, and end ups with mapping and statistical modeling (Sen et al., 2008; Durduran et al., 2010; Moraru and Marica, 2011).

Many studies in different countries concentrated on mapping the pollution of the EMF radiation with different standards for the radiation limits (Australian standard 200µW/

* Corresponding author. e-mail: alakmoh@just.edu.jo

cm^2.; Russia, Italy and Canada allow only 10µW/cm^2; China, 6µW/cm^2 and New Zealand 0.02µW/cm^2). Surprisingly, cell phone towers in the United States are most lenient and least protective in the world - US allows 580 to 1,000 µW/cm^2 (Aldad et al., 2012). Durduran et al. (2010) studied the effect of EMF radiation of cell-phone towers, in order to map the pollution of the EMF radiation in Turkey. They found that the most intense area of EMF fields was in the center of the city and concluded that there is a strong relationship between the levels of EMF pollution and health. Giliberti et al. in 2009 studied the EMF radiation effect of radio base station (RBS) in Italy. They found that the exposure produced by electric field was less than the exposure limits stated by Italian standards (Giliberti et al., 2009). In contrast, effect mobile radiation is harmful and more destructive on liver tissue (Ghaedi et al., 2013), 2.1 GHz W-CDMA modulated MW radiation inhibited cell viability and induced apoptotic cell death via the mitochondrial way (Esmekaya et al., 2013). From the survey performed by Ammoscato et al. in the urban area of Palermo, values under the threshold have been obtained, about 2.2 V/m (1.2838 µW/m^2), except for some positions near Piazza Alcide De Gasperi, where maximum peaks of 10.18 V/m (27.4887µW/cm^2) have been recorded (Ammoscato et al., 2008). Gotsis et al. (2008) measured the variation of the electric field strength values on majority of the stations site and found to be below 3 V/m (2.387 µW/cm^2) which they consider it as a negligible value. Pollution analysis in a given propagation environment was done in a building of Yildiz Technical University, Turkey and found that Wireless Local Area Networks, WLAN (2.4 GHz) electromagnetic coverage does not lead to any electromagnetic pollution due to the low power levels used were the building generated using the selected network architectures to illustrate the results with an Artificial Neural Networks (ANN) (Sen et al., 2008). Results of other researchers suggests that GSM-EMFs of a mobile phone affect inter-hemispheric synchronization of the dominant (alpha) EEG rhythms as a function of the physiological aging (Vecchio et al., 2010), in contrast to a recent study by Trunk et al. (2013) found no measurable effects of a 30 min 3G mobile phone irradiation on the EEG spectral power in 1947 MHz UMTS RF exposure. Similarly p53 expression and its activation by phosphorylation in embryonic cells are not induced by exposure to GSM-900 MHz (Bourthoumieu et al., 2013), no any elevated risks of childhood leukemia associated with RF-EMFs (Merzenich et al., 2008).

Recently, World Health Organization (WHO's) international research agencies has classified electromagnetic fields from mobile phones and other sources "possibly carcinogenic to human" and advised the public to adopt safety measures to reduce exposures, like use of hand-free devices or texting. In this regard, with the rapid growth of the mobile users in Jordan, more than 6 million mobile phones are used in Jordan as reported by Telecommunications Regulatory Commission (TRC), which is more the number of populations about 103% in average. Most Jordanians have more than one cell phone or more than one line from different cell phone providers. Mobile towers are being built in a haphazard manner without any prior planning and regulation. People in Jordan nowadays raised real concern about the lack of cell-phone safety standards and policies and the adequacy of these standards to protect Jordanians. In light to evidentiary uncertainties and lack of public awareness about the cell-phone safety standards, we found that it is quite useful for our research team at Jordan University of Science and Technology (JUST), the Jordanian decision makers and civil societies to study the cell-phone towers EMF radiation in pilot regions in north Jordan. EMF radiation levels from selected base stations and certain spectrum range were measured using isotropic broadband and portable spectrum analyzer measurement. The results were processed in a digital map and interpolated using the ArcGIS9.3 software. Furthermore, to compare the exposure of EMF radiation mechanisms in the far-field region with standard levels, mapping and simulation of our data was also conducted and correlated with safety regulations.

The major goals of this research are; to provide quite graphical representation of the relatively high exposure levels (hotspots) and to identify the frequency, intensity, and dose of non-ionizing electromagnetic fields that could be harmful to the biosystem and ecosystem in Jordan;to provide experimental data as a solid evidence for the dissension makers in Jordan to guide and enable them to built-up a national strategies for the proper and ethical use of wireless technologies. Moreover, the financial revenues for cell phone providers must not be the only dominating factors when issues come to health risks and radiation pollution of the environment.

2. Methodology

In this study, ten selected cell tower sites in the north of Jordan at various locations with relatively high electromagnetic radiation intensity are studied. Just three of them namely; Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center are presented in this manuscript. Experimental measurements of the cell-phone towers EMF radiation levels through detection, modeling and analysis was done using a portable experimental set-up described below.

The sites were divided into several environments (plains, plateaus, mountains …etc) nearby crowded buildings (residential, schools, hospitals, companies ....etc). Collected information about the technical data of the selected cell-phone towers, such as: (type of antenna, its gain and radiation pattern, vertical tilt (azimuthal) and frequency band), which is needed for the classification process was recorded. In order to evaluate the EMF cell-phone tower radiation, the total emissions in all locations was calculated, taking into account the total contribution of each tower. Throughout field data collection, we measured the total radiation, intensity of electric-field, magnetic-filed and power density in several points for each exposure site. The instrument and software used are Radiofrequency EMF strength meter (Extech Instruments frequency range 50 MHz to 3.5GHz, Model: 480836/USA), Handheld Spectrum Analyzer (Agilent Technologies frequency range 100KHz to 3.0GHz, Model: N9340B/USA) Magellan Explorist (Model: 510/USA), GPS device and ArcGIS 9.3 software. All points where located using GPS device to identify location coordinates (latitude, longitude and altitude) around the sources. The GPS is deemed as an outstanding navigational system due to the following: its capability to attain high positioning accuracy (ranging from tens of meters down to millimeters) and its signal availability to users anywhere on the globe (air, ground, and sea applications).

In addition, we used spectrum analyzer to identify RF sources and for assessment of the relative magnitude of signals in different frequency ranges. Spectrum analyzer with a calibrated antenna gives a sensitive and precise channel power measurement across selected frequency ranges and also provides precise measurement of strength for an individual signal for each source in the selected sites. To analyze data, electric field (E) and magnetic field (H) ware calculated by applying the classical field equation of the EMF intensity in the far-field region (the region extending farther than 2 wavelengths away from the source is called the Far-Field). As the electromagnetic waves transmitted through space, the energy is transferred from the source to other objects (receiver). The rate transfer of this energy depends on the strength of the EMF source where it becomes a rate of energy transferred per unit area (power density), which is the cross product of the electric field strength (E) and the magnetic field strength (H). In the far-field, E, H, and power density are combined together. Thus by measuring the electric field, we were able to calculate the power density ($P_d = E^2/377$) and the value of the magnetic field ($H=E/377$). Power level measurements were performed for base station in far-field points ($R>2D^2/\lambda$). The detector minimal distance used was about several meters from a portable detecting device.

Data collected from the power strength meter and the GPS devices were tabulated as the power density and location at each point. ArcGIS 9.3 was used to provide a map of the EMF data, based on the mapped EMF radiation at various points in each site. The software plot the 2D and 3D maps using interpolation depends on inverse distance weighted (IDW). The interpolation technique estimates point values by averaging the values of sample data points around each processing point. Thus, new values could be found by IDW technique, which assumes that each point has a regional effect; the effect is inversely proportional to a distance between interpolation point and measurement point. Eventually a comprehensive digital 2D and 3D map of the selected regions is produced. Data obtained using spectrum analyzer in each cell tower site were analyzed and compared with other selected locations. Highest radiating sources and average power density for each location are represented in histograms.

3. Results

In all figures the cell towers locations are marked with stars and measurement points are marked with dots. Selected location and cell phone towers sites with different environmental condition are presented as follows:

Fig. 1 shows a Google and 2D ArcGIS maps of site Ajloun-Ebleen. At this site, power densities of three cell towers from different points around the towers were collected and recorded. In this region, places under investigations were as follows: crowded residential area nearby cell-towers, places far away from residential area and towers, and most frequently visited places such as mosque, church, school, shops, health center and farms. Mapping of the power densities are shown in Fig. 2a, (2D) and 2b (3D). Red color represents the hotspots where places received high radiation doses.

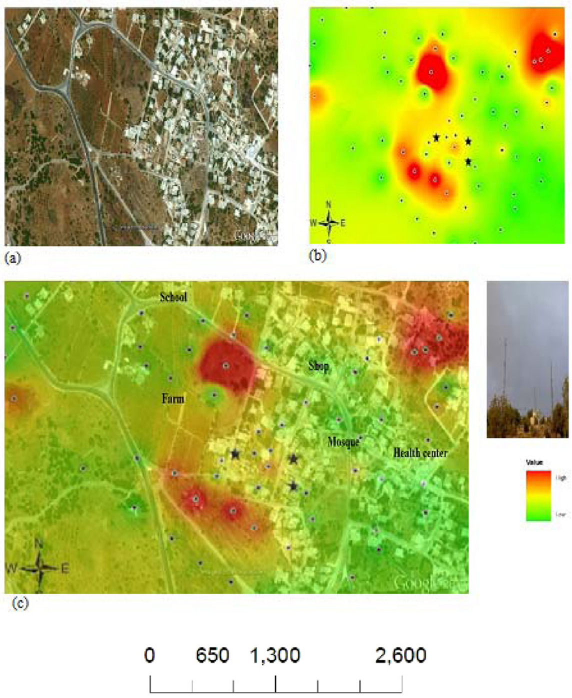

Figure 1. (a) Google earth map of Ajloun-Ebleen site (b) 2D areas map by ArcGIS9.3 (c) the tow maps (a and b) are superimposed. The cell tower location is marked by a star and the dots represent the measurement points.

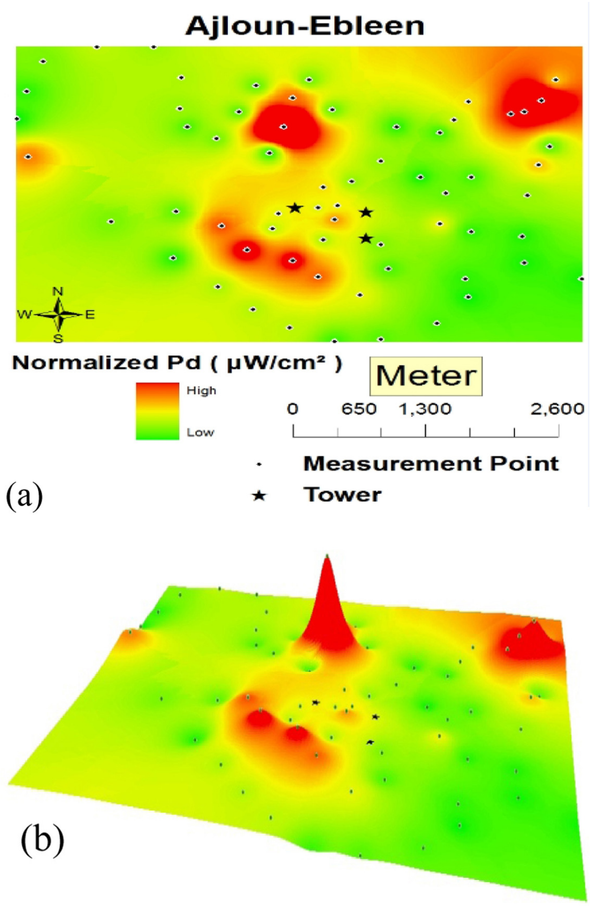

Figure 2. (a) 2D & (b) 3D representation of measurement values at RF radiation in Ajloun-Ebleen.

Fig. 3 shows a Google and 2D ArcGIS maps of site Irbid-BeitRas. At this site, a group of three cell towers locations are marked by a star at the 2D map. A Radio and TV Stations are installed at this site to covers the northern part of Jordan. VHF/UHF radio and TV towers are placed on the highest point in an area so the transmitted signal has a clear path to receiving antennas. The 3D mapping of the power densities is shown in Fig. 4.

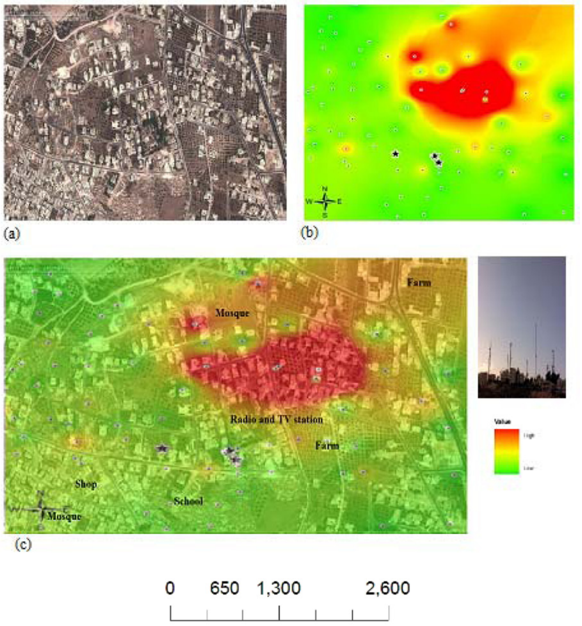

Figure 3. (a) Google earth map of Irbid-BeitRas (b) 2D areas map by ArcGIS9.3 (c) the tow maps (a and b) are superimposed. The cell tower location is marked by a star and the dots represent the measurement points.

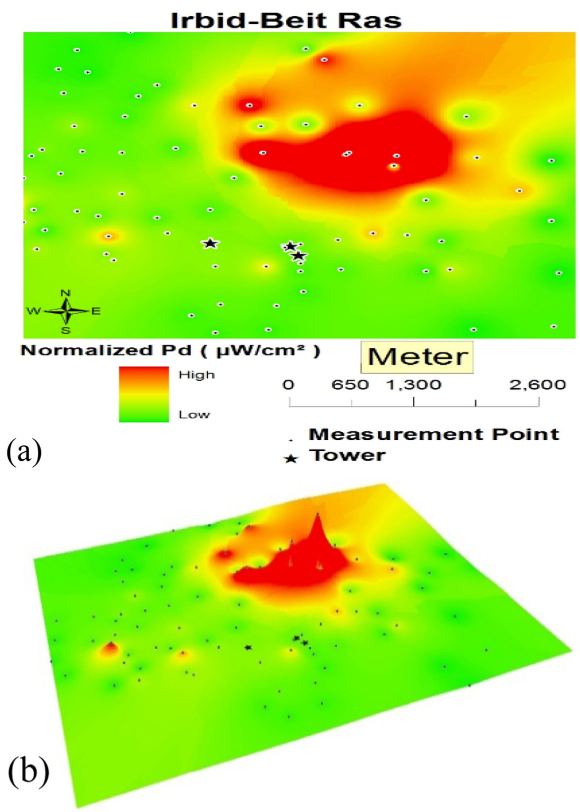

Figure 4. (a) 2D and (b) 3D representation of measurement values at RF radiation in Irbid-BeitRas.

The transmitted antennas patterns in this area are designed so that the radiating beam is projected away from the tower almost horizontally to cover as much areas as possible. This minimizes the signal strength at ground level near the tower. The higher level fields occur at a height that not accessible to the general public. Therefore, residence living nearby cell phone towers received weak coverage with low radiation dose.

Since Irbid is the largest crowded city in north Jordan with a population of more than one million, an extensive effort is required on EMF radiation detection and assessments by the health organization and national research institutes. The city has so many educational, industrial, health and commercial centers. Our initial survey study found that there are various sources of EMF radiation such as: Cell towers, roof towers (microcells) which operate 2G, 3G, FM Radio and TV stations. A typical example of cell towers radiation map in some of selected site in Irbid city center are shown in Fig. 5. There are three cell towers in the selected site. Two are roof towers and one huge stand alone cell tower in the middle. Collected data points of the power densities around those three towers are plotted in 2D and 3D mapping as shown in Fig. 6.

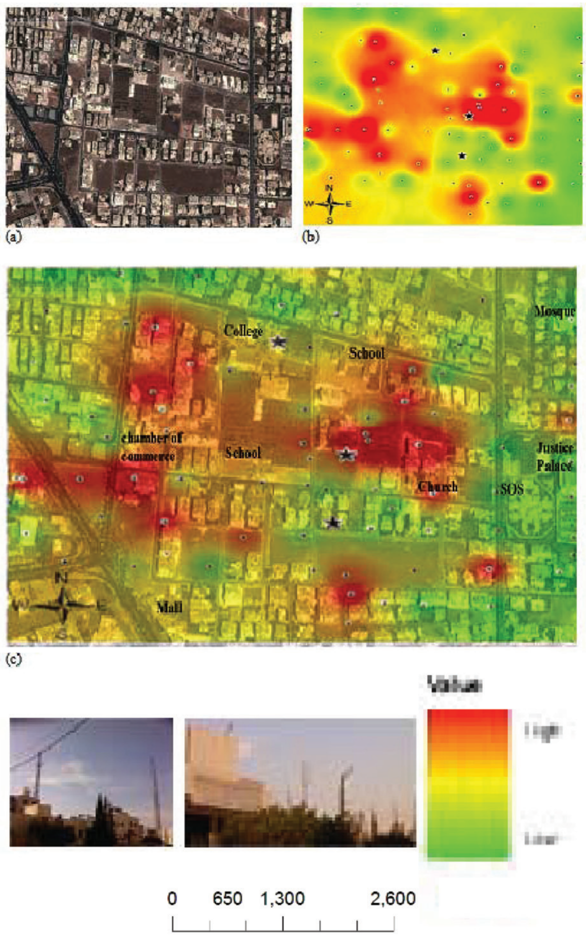

Figure 5. (a) Google earth map of Irbid City center (b) 2D areas map by ArcGIS9.3 (c) the tow maps (a and b) are superimposed. The cell tower location is marked by a star and the dots represent the measurement points.

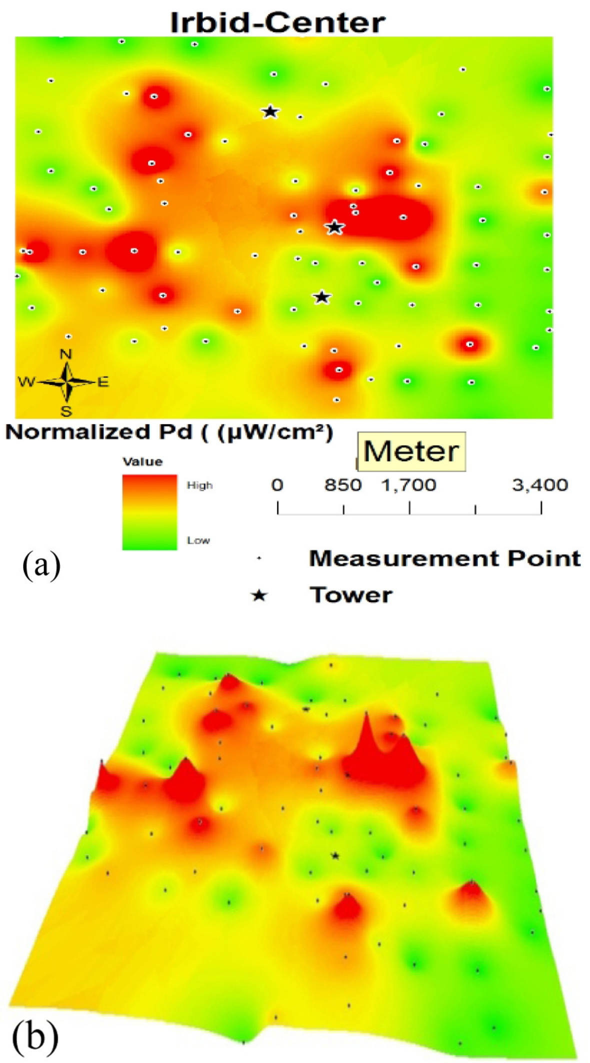

Figure 6. (a) 2D and (b) 3D representation of measurement values at RF radiation in Irbid city center.

Comparison between measurements of spectrum analyzers and RF power meters.

A comparison of the power density measurements using Spectrum Analyzer and Power Meter are shown in Table 1. Average RF exposure measurements for all cell towers in Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center are summarized in Table 2 and Fig. 7. Frequency band measured by spectrum analyzer at the selected locations Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center are shown in Fig. 8.

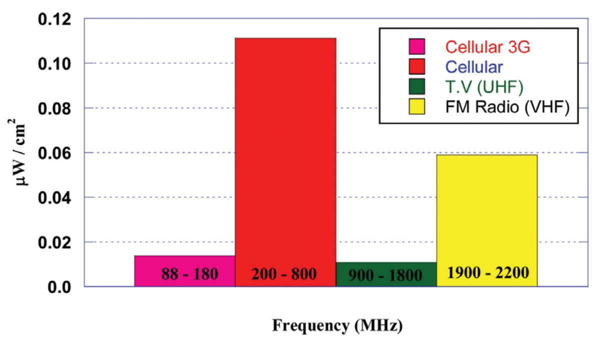

Figure 7. The average RF exposure measurement for all cell towers in Ajloun-Ebleen, Irbid-Beit Ras and Irbid city center by using spectrum analyzer-Agilent N9340B/USA.

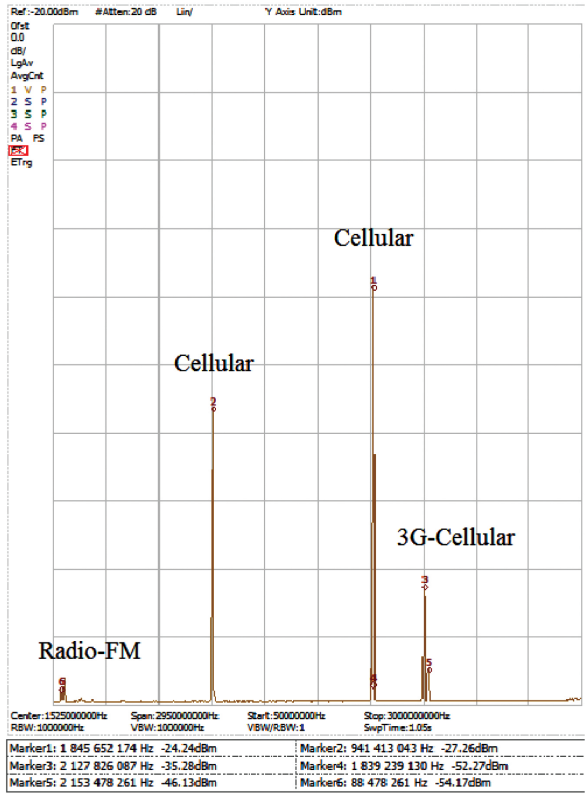

Figure 8-a. Ajloun-Ebleen

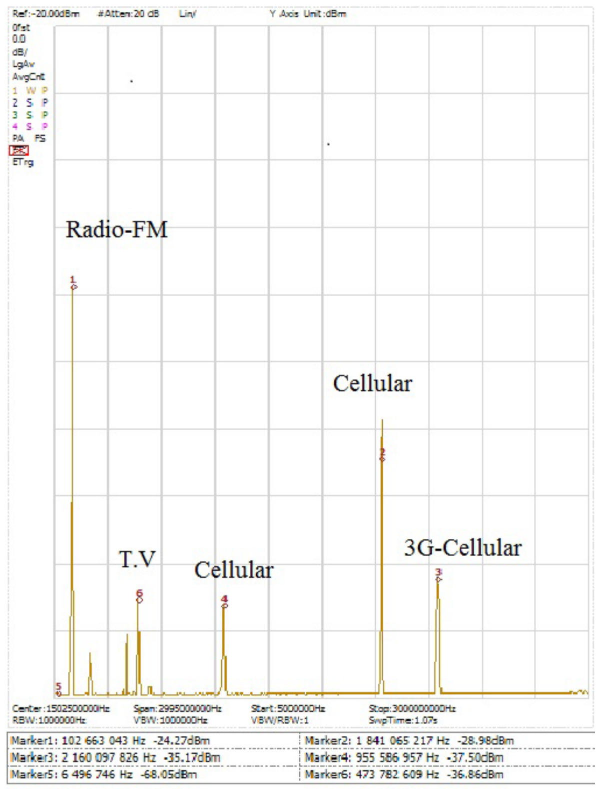

Figure 8-b. Irbid-Beit Ras

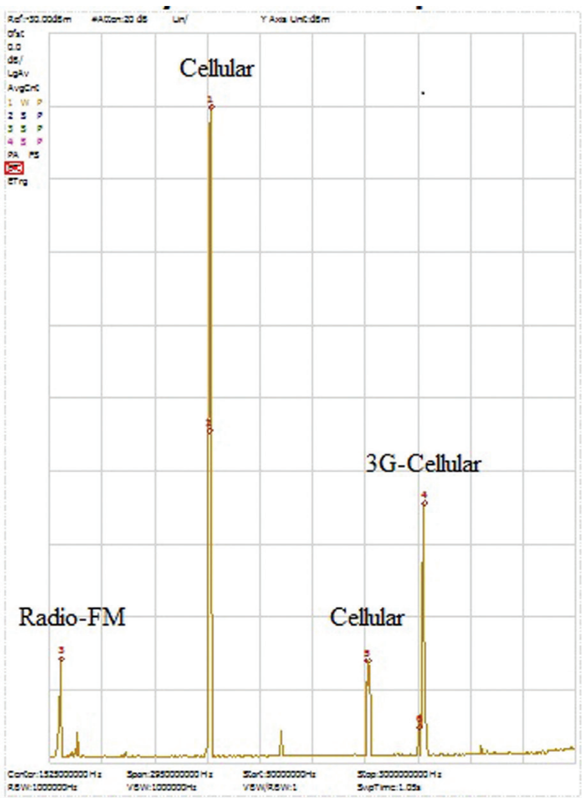

Figure 8-c. Irbid city center

Figure 8. Frequency band from the spectrum analyzer-Agilent N9340B/USA with spectrum range (50 MHz to 3GHz) at the selected locations; 8. a: Ajloun-Ebleen, 8. b: Irbid-Beit Ras and 8. c: -Irbid city center.

Table 1. Comparison between the measured values for RF radiation levels emitted of spectral subdivision by spectrum analyzer and power strength meter at different locations in Northern part of Jordan.

Location	Average Power density (μW/cm²)	
	RF Power Meter	Spectrum Analyzer
Ajloun-Ebleen	0.0835	0.2003
Irbid-Beit Ras	3.5400	0.2722
IrbidCityCenter	0.1350	0.1745

Table 2. RF radiation levels of spectral subdivision by spectrum analyzer- Agilent N9340B- for all cell tower sites.

Location	FM Radio (VHF)	T.V (UHF)	Cellular	Cellular 3G	RF expose
Ajloun-Ebleen	0.0019	0.0001	0.1790	0.0192	0.2003
Irbid-Beit Ras	0.1740	0.0219	0.0725	0.0038	0.2722
IrbidCityCenter	0.0009	0.0000	0.1500	0.0235	0.1745
Average	0.0589	0.0109	0.1113	0.0137	0.2157

4. Discussion

Fig. 1 and Fig. 2 represent the measurement values of EMF radiation in Ajloun-Ebleen. The power densities at the most populated residential area of the city are low. Relatively high power densities were measured at different places outside residential area.

The maximum reading of the power density was 0.083μW/cm² from the power meter and 0.200μW/cm² from the spectrum analyzer. Those obtained readings are from empty locations with no buildings or people living around. This suggests that the randomness in the cell tower site selection process indicates that there are no regulations and real time studies for the radiation levels done by the cell phone providers and the official telecommunications departments in the country. It gives clear evidence that the cell towers were installed and designed in a haphazard way without taking into account the human exposure to the EMF radiation or even the transmission coverage areas. Mapping of our collected experimental data are plotted in 2D and 3D as shown in Fig, 1 and 2. In those figures, clear hotspots are marked with red colors. Similarly mapping with comparable findings is reported by (Gumusay et al., 2007). In their study 3D electromagnetic coverage and electromagnetic pollution modeling with Artificial Neural Network (ANN) using back propagation algorithm is realized and modeled in GIS environment. Average of ANN is about 0.261 V/m which is nearly equal to 0.0180 μW/cm² [Gumusay et. al., 2007]. Furthermore, similar hotspots were assessed reported by (Aerts et al., 2013), the maximum total electric-field strengths ranging from 1.3 to 3.1V/m (0.448 to 2.5491μW/cm²) were found and satisfy the reference levels issued by the International Commission on Non-Ionizing Radiation Protection for exposure of the general public to RF-EMF. Spectrum analyzer measurements in these hotspots revealed five radio frequency signals with a relevant contribution to the exposure (Aerts et al., 2013).

Measurements of typical transmitter sites in Irbid-BeitRas showed that the signal levels on the ground near the towers are typically 1% or smaller than the general public exposure limits Fig. 3 and 4. The low level values are may be due to transmitted antennas pattern in this area which are designed in such a way that the radiation beam is projected almost horizontally to cover as much areas as possible. Therefore, minimum signal strength at ground level near the tower is measured and higher power levels were measured at heights that are not accessible to the general public. Even though, in our study, the maximum power density recorded by the power meter at this site was 3.54μW/cm² and this was the highest value for all selected sites while the maximum reading of the power density recorded by spectrum analyzer was 0.174μW/cm². These spots with relatively high radiation levels indicate that people who are living or working in or nearby the TV and Radio stations are potentially exposed to EMF radiation hazards.

Fig. 5 and 6 represents the measured values of EMF radiation in Irbid-city center. It can be easily seen that the radiation coverage is much more distributed over the region than what we have observed in the other sites. Note that most of the main buildings are under a relatively high radiation levels. Furthermore, we have seen at many places a building's roof has up to two or three towers on first floor and these towers in some cases are directly facing second floor of adjoining building similar to that at Yarmouk University Street. This street is internationally well-known because it is less than 1 km long but has more than 130 Internet cafes, making it one of the densest streets worldwide in number of Internet cafes. The number of internet cafes per capita is the highest in the world that may took Irbid to the Guinness Book of World. The maximum average reading of the power density at some accessible places was 0.135μW/cm^2 from the power meter and 0.174μW/cm^2 from the spectrum analyzer. Researchers in some other countries report several exposure values in several locations. For example, if a mobile phone base station is mounted to the roof of the office building or another nearby building, EMF exposure levels can increase to several thousands to ten thousands of microwatts per square meter (Thansandote et al., 1999; Sage, 2000). If the base station sits at the disk, continuous RF radiation exposure can range from about 2 μW/cm^2 (1 m distance) to about 350 μW/cm^2 (20 cm distance) (Kramer et al., 2005). Another study, reported a fourfold increase in the incidence of cancer in people living within 350 meters of a cell phone tower as compared to the general population. They also reported a tenfold increase specifically among women (Wolf et al., 2004). Significant changes of the electrical currents in the brain by a cell phone base station at a distance of 80 meters were also reported (Lebedev, 2010). It has been reported that, when holding the handset against the head during a call, EMF radiation exposure will be even higher. In the case of a mobile phone handset, the head's exposure was quite above 100 μW/cm^2 (Maes, 2005). Overall, our obtained results could be helpful to cell phone towers and EMF designers to consider queries concerning the electromagnetic radiation, coverage, environment pollution, and helps to determine the communication signal quantity and quality. In addition, further investigations should be conducted at these special areas. From our data analysis we found that cell phone providers in Jordan don't build sites where they expect future population growth; they build because there is a specific and current need and most of these sites are randomly distributed throughout the whole areas in north Jordan without any professional mapping of the real signal coverage needed at these areas.

Northern part of Jordan is known for its wonderful wildlife, nature reserves, and beautiful mountain which contain one of the last remaining examples of a pine–oak forest in the Middle East. Despite the apparent efforts to protect these and unique areas, it is gradually and systematically being destroyed by the establishment of modern cement projects for industrial and commercial purposes. Moreover, with the communications revolution during the last two decades, cell towers in all shapes and sizes have invaded the virgin environment and thousands of new communications towers have been installed randomly in the cities and the countryside. Unfortunately, the telecommunications regulations make it illegal for local governments to reject installations of new towers. The law also makes it difficult, and in many cases impossible, for communities to restrict the size, location, appearance or number of towers. Despite huge number of cell towers distributed almost everywhere, still peoples in some areas are complaining a lack of towers close to them due to low transmission coverage.

In this work and for the first time in Jordan we raise concern about the environmental pollution of cell tower radiation. To do this, we have selected some tower sites in the cities of Irbid and Ajloun and their rural areas in north Jordan. Measurements have been made at locations that could be assumed to have higher radiation levels than would be the case if measurement locations were selected randomly. In light of the sites selection discussed above, one can take the precautionary principle approach and reduce EMF radiation effects of cell phone towers by increasing height of towers, changing the direction of the antenna, or relocating towers away from densely populated areas and placed where they don't harm people (Sivani et al., 2012). The Orange phone company in Bristol, England is being forced by residents and local authorities to remove its cell towers when cancer rates in the building raised ten times above the national average (Lebedev, 2010). Furthermore, all measurements have been stationary, and there is today no knowledge about the level of exposure that an individual will have throughout the day. In the selection process, the drive short aims were to check radiation levels from cell towers located in vicinity of schools, mosques, churches, hospitals, wildlife and residential areas, while the long term project is to cover the whole country taking into account the health issue. In addition to long term goals, protection and EMF shielding will be studied.

4.1. Power Measurement of the Selected Sites

A cell tower and its transmitting power are designed in such a way that cell phone should be able to transmit and receive enough signal for communication up to a few kilometers. Majority of these towers are mounted close to the residential and office buildings to provide good mobile phone coverage to the users. These cell towers transmit radiation day and night, so people living within in the vicinity of the tower will receive more than ten thousand times stronger signal than required for cell phone communication.

An antenna transmits in certain frequency band. This frequency band is divided into sub-bands, which are allocated to different operators with several carrier frequencies allocated to one operator. Each carrier frequency may transmit 10 - 20W of power and the total transmitted power may be 200 to 400W. In addition, directional antennas may have a gain of around 17 dB, so effectively; several kilo watts of power may be transmitted in the main beam direction. However, radiation density will be much lower in the direction far away from the main beam.

ICNIRP guidelines has givens adopted radiation norms in Jordan for safe power density of f/200, where f is the frequency in MHz, and the transmitting band is (935-960 MHz) for GSM900 with a power density of 4.7W/m^2 and transmitting band (1810-1880 MHz) for GSM1800 with a power density of 9.2W/m^2. One of the most significant RF radiation signal measurement problems, and one responsible for some of the greatest inaccuracy, involves an instrument erroneous response that can occur when there are two or more strong signals present at the same time. Instrument design can minimize this problem, but many of the commonly used isotropic broadband meters perform very poorly in this multi-signal environment. The result is a reading that is much higher than actual; sometimes double. In this study, we have measured the power density by using both the sensitive spectrum analyzer and the power meter. The use of these instrument with a calibrated antenna will allow a sensitive and precise "channel power measurement" across selected frequency ranges, or measurement of the strength of an individual signal. The measurements were repeated several times during a fixed time interval of and averaged for each point in all possible direction near the cell tower site. The data of the two methods were compared and discussed.

An additional challenge results from the fact that power density levels at a cell tower site itself are not always constant, as they usually are at a broadcast antenna site. People use their cell phones more at some times of the day, and on some days of the week, than at others. The cell phones providers maintain additional capacity in the form of multiple channels which will become active as needed to meet demand. Each active channel adds to the measured power density at the cell site. The variable nature of power density levels at some sites must be taken into account. When necessary, we employ timed signal averaging or data logging to produce an accurate assessment.

4.2. Mapping of EMF Radiation Levels

Measured data using the Spectrum Analyzer, Power Meter and GPS has been used to make interpolation over complete area in the IDW (Inverse Distance Weighted) module of ArcGIS software. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. Thus, new values can be found by IDW method. This method assumes that each point has a regional effect and this effect is inversely proportional to the distance between interpolation point and measurement point. Similarly, ArcGIS software was used to make a 2D and 3D map from the data. The area having various radiation levels was determined by combining this data with digital Google map of all selected sites showing radiation levels in different colors have been set up, by using the data obtained. Through this map, areas with relatively high power densities were identified easily in the vicinity of the cell tower. It has been found that some cell towers had relatively higher radiation values compared to the others. In the following we will present these maps for each site alone and compare them with some other measured and standard values.

4.2. Comparison between Spectrum Analyzers and RF Power Meters

RF power meters are used not only for measuring power levels in RF systems, broadcast systems, and radar/satellite systems, but for calibrating other measurement instruments and probes are needed. Unfortunately, an RF power meter is designed for broadband frequency coverage and cannot determine the carrier frequency associated with a power reading or whether the measured power is within the proper bandwidth or not. Normally, a spectrum analyzer is also needed to get these determinations. No matter where the RF signal is centered, the power meter reads the same total average power value. However, the RF power analyzer is programmed to read the power only in the channel in which the mobile device is supposed to be transmitting. Moreover, the ability of the RF power analyzer to measure power within specified frequency bands enables it to spot defects that an RF power meter cannot.

Conclusions

We argue that due to potential radiation hazards, these existing cell towers near schools, hospitals and residential areas must be moved out of such areas, as studies show that radiation levels at such facilities could cause cancer, miscarriages, disturbance of the nervous system and other diseases. Large disparities between national radiation exposure limits and international guidelines based on contradictory studies can foster confusion for regulators and policy makers, increase public anxiety and provide a challenge to manufacturers and operators of communications systems. In this regard, well designed and conducted useful and information studies should be known to all, because negative results (no effect observed, below standards) are as useful as positive studies (effect observed, above standards) when evaluating the scientific evidence. Furthermore, radiation exposure standards that limit human EMF exposure should be based on studies from various disciplines of health sciences, including biology, epidemiology and medicine, as well as physics and engineering. All of these play important individual and collective roles in identifying possible adverse effects on health and in providing information on the need for, and appropriate levels of, protection.

In Jordan, unsystematic with random location of RF-EMF sources over all the place form all the cell phone companies are noticed. Similarly, haphazard exposures with very high range in some places and sometimes empty places were found. Therefore, we believe that it is time now for national advisory and/or regulatory bodies to develop new standards for EMF, review the basis of their standards, or reconsider specific quantitative values such as reference levels and safety factors. The overall purpose of this protocol is to provide advice on how to develop science-based exposure limits that will protect the health of the public and workers in Jordan from EMF exposure. Up to our knowledge, this is the first studies in Jordan and therefore further studies should address these issues in more details and more locations should be covered. In conclusions and on the bases of our study it is recommended that installation and operation of a cell towers should be subject to protocol or guidelines, searching for alternative locations for the cell-towers with monitoring before and after installation, and conducts laboratory studies and monitors external research on the biosystem and ecosystem.

Acknowledgements

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Temporal and Spatial Analysis of Climate Change at Northern Jordanian Badia

Alaa Abu Sada[1], Mahmoud Abu-Allaban[1]*, Ahmad Al-Malabeh[2]

[1]Department of Water Management and Environment, The Hashemite University, Jordan
[2]Department of Earth Sciences and Environment, The Hashemite University, Jordan

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Abstract

Scientific evidence continues to mount that the earth's climate is changing rapidly. Global average surface temperatures have increased by about 0.7 degree Celsius since the beginning of the 20th century, and nine of the ten warmest years on record have occurred during the 21st century. Climate change is among the biggest threats that face humanity. As temperature and precipitation patterns change, the delicate balance of climate, weather events and life is disrupted. The present paper aims at investigating the impact of climate change on air temperature and annual precipitation in the Jordanian Badia, which has fragile environmental ecosystems. Meteorological data for six meteorological stations in the Badia (Mafraq, Safawi, Rwaished, Azraq, Um El-Jumal, and Ramtha) in addition to Dara'a at south Syria, and Turaif and Guriat at North Saudi-Arabia obtained from the Jordanian Ministry of Water and Irrigation and the USA national oceanic and atmospheric administration (NOAA) are used to identify the changes in air temperature and precipitation. The statistical package for the social sciences (SPSS) is utilized to retrieve a regression trend between atmospheric carbon dioxide and ambient air temperature and to project future air temperatures at the nine stations considered in this study. Findings indicate that air temperature is increasing at an annual rate of 0.02-0.06 °C/year and annual precipitation is decreasing at an annual rate 2.6-0.5 mm/year.

Keywords: carbon dioxide, global warming, climate change, precipitation, air temperature

1. Introduction

Meteorological data collected at Monalue Island indicate that air temperature has shown a steady and gradual increase especially in the past decades (IPCC, 2007). The Earth's average surface temperature has risen by 0.76° C since 1850 (IPCC, 2007). It is believed that the ongoing air temperature rise is attributed to the intensification of the greenhouse effect, which is primarily caused by carbon dioxide and other greenhouse gasses (Meehl et al., 2007).

One of the most important and immediate effects of the ongoing climate is the reduction in fresh water (Xu et al., 2005). Effects include the magnitude and timing of runoff, the frequency and intensity of floods and droughts, rainfall patterns, extreme weather events, and the quality and quantity of available water (Arora, 2001). Climate change is likely to alter the hydrological cycle through increasing the surface air temperature and rates of evapotranspiration. Changes in the total amount of precipitation and its frequency and intensity directly affect the magnitude and timing of run-off and the intensity of floods and droughts.

Jordan is vulnerable to the devastating impacts of climate change, especially in water and agriculture sectors that are linked to socio-economic conditions (UNFCCC, 2009). It is particularly important to detect any trends in air temperature and precipitation in Jordan, with particular emphasis on the Badia, which is becoming an important agricultural and residential area. Harrison (2009) argued that the major problem of biodiversity and conservation in Jordan due to climate change will be intensified drought. The author estimated that air temperature will increase by 3±0.5°C in winter and 4.5±1°C in summer by the end of the 21st century and there is little or no change in precipitation to offset these large increases in temperature.

Hammouri and El-Naqa (2007) conducted a research to assess drought conditions in Amman-Zarqa basin of Jordan and reported that the drought periods had repeatedly occurred in a regular manner during the last 50 years in the investigated catchment area. To the contrary, Dahamsheh and Aksoy (2007) did not find any trends in Jordanian precipitation data at 13 stations investigated for the years 1953–2002. Al-Qudah and Smadi (2011) reported that Jordan, which is part of a semi-arid zone, is vulnerable to climate change. Ghanem (2010) analyzed meteorological data of the rainy seasons from 1956/1957 to 2005/2006 at 11 stations distributed within Amman area and reported that annual precipitation is decreasing by about 0.4 mm/year, but with no statistical significance. He also reported that the running means show two wet periods (1962/1963–1973/1974 and 1987/1988–1993/1994) and two dry periods that occurred in the beginning and the end of the study period.

The Badia is the main source of summer vegetables and fruits, and most livestock is raised there. An emerging

* Corresponding author. e-mail: mlaban@hu.edu.jo

humanitarian factor has also emerged due to the influx of a vast number of Syrian refugees who are anticipated to exceed two million persons if the Syrian civil war does not come to an end soon, which places an extra pressure on the stretched water resources in the Badia. For all these reasons, it is very important to better visualize how the climate change is going to impact the Jordan Badia, particularly in terms of air temperature and precipitation. Therefore, the main objective of this thesis is to study the temporal and spatial climate change in the Jordanian Badia and stations in neighboring territories.

2. Climate of Jordan

Jordan is situated at about 80 kilometers east of the Mediterranean Sea between 29º 11´ to 23º 22´ North, and 34º 19´ to 39º 18´ East. The area of land mass is approximately 88,778 Km^2 while the area of water bodies that includes both the Dead Sea and the Gulf of Aqaba is approximately 482 Km^2. Altitude ranges from about -415 m (below mean sea level) at the surface of the Dead Sea up to 1845 m at top of Jabal Um Ad Dani (MWI, 2009). Most of Jordanian territories (more than 80%) are either Badia or Desert; its climate is classified as arid to semi-arid (MWI, 2009). Jordan has three main topographic features; desert, mountains, and Jordan rift regions (MWI, 2009). The annual rainfall distribution varies with location from more than 600mm at Rasmuneef Summit in the northern highlands to less than 50mm in the eastern and southern deserts (MWI, 2009). The long term average accumulative precipitation of Jordan in last decades (1937 - 2006) averages around 8325 mcm/year, which is equivalent to about 93 mm per square meter per year.

North-Western parts of the country enjoy a Mediterranean climate, while eastern and southern deserts exhibit a sub-Sahara climate. The climate is hot and dry in summer months but mild and wet in winter. The rainy season extends from October to April. Most of the precipitation falls in the form of rain or drizzle. However snow may fall on highlands and hail is not unusual but it is associated with atmospheric instabilities during winter fronts or thunderstorms, which occur during warm spring days (UNFCCC, 2009).

According to Freiwan and Kadioglub (2008), Jordan can be divided into three regions based on annual precipitation:

(1) Wet region which includes Northern Heights, Western Amman, Assalatune, Jerash, Ajloon, and Irbid in addition to the northern Jordan Valley (Baqura). The total annual rainfall in this region varies between 400 and 600 mm.

(2) Semi-arid region which includes central part of Jordan such as East- and South-Amman, central heights (Shoubak and Rabba), and the middle Jordan Valley (Deir Alla). This region has annual rainfall in the range of 250-350 mm/year.

(3) Dry region which includes Eastern Hills and Badia plateau such as Wadi Duleil, Zarqa, Mafraq, Azraq, the eastern parts of Safawi and Ruwaished, southern and southeastern parts (Ma'an and Jafr) and southern Jordan Valley that extends to Aqaba. Annual precipitation in these regions varies between 140–170 mm in the central west, 70–90 mm in the east, and 30–50 mm in the south.

3. Study Area

The Badia area extends from north to south in the eastern part of Jordan, covering about 80% of the country's total area. The total population of the Badia represents about 5% of the whole population of the country. Only 5% of the Badia population is still nomadic (MWI, 2002). The total area of the northern Badia is 25,950 km^2 (Figure 1), which constitutes 36% of the total area of the Jordanian Badia. According to 2007 census, the total population of the northern Badia is 160 thousands living in 110 different urban settlements. This area is characterized by its unique location (Mafraq governorate) where it shares its borders with three Arab countries (Syria, Iraq and Saudi Arabia). Administratively, the northern Badia is divided into 3 districts (Ruwayshid, northern Badia, and northwestern Badia) and 7 sub districts (Sama As-sarhan, Hosha, Dair Al-kahf, Sabha, Um alJimal, Um Al-Quttain, Al-Khaldiyah). The Badia holds numerous and rich natural resources in quantities adequate for overall developmental requirements. Beside the vast area available for development, resources include mineral deposits, surface and groundwater, touristic sites, sunny weather, renewable natural range and cultivable land suitable for improved agriculture and livestock production. The area also has a potential for the development of non-pollutant renewable energy sources, namely solar and wind energy. As the Badia extends into the borders of neighboring countries, there is an additional benefit of its being a junction for export-import activities at the regional level.

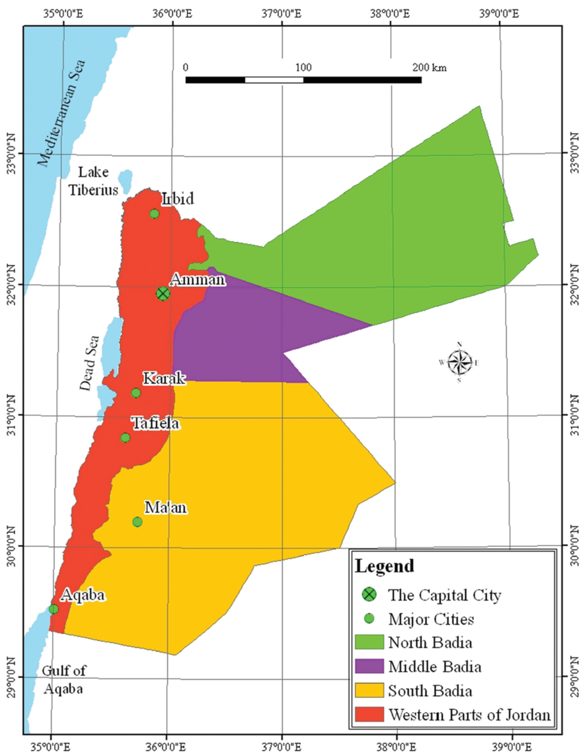

Figure 1. Study area.

4. Statistical Data Analysis

4.1. Data Collection

Nine meteorological stations are selected to study the impact changes in the northern Badia (Table 1). Compiled database includes meteorological parameters such maximum and minimum daily air temperature, mean daily air temperature and daily precipitation. The data were obtained through the Jordanian Ministry of water and Irrigation, and the data center of the National Oceanic and Atmospheric Administration (NOAA), which is considered the world's largest archive of climate data.

Table 1. Meteorological stations that are selected to investigate climate change in Northern Badia

Station ID	Station Name	Time Interval Start End		North (JTM)	East (JTM)
F 0009	Azraq	06/1968	06/2011	525422.63	480628.28
AL0059	Um El-Jumal	06/1968	06/2011	575013.63	438260.31
AD0012	Ramtha	5/1976	12/2005	604961.08	405610.35
40265099999	Mafraq	12/1983	04/2012	583384.93	428124.59
40250099999	Rwaished	01/1963	04/2012	598394.42	611052.84
40260099999	Safawi	01/1964	04/2012	564623.05	508800.64
40095099999	Dara'a	09/1977	05/2011	609651.55	424372.22
40360099999	Guriat	02/1985	05/2012	474714.75	526910.06
40356099999	Turaif	03/1963	05/2012	508337.44	663586.08

4.2. Data Processing

Assessment of climate change at Northern Badia is performed based on climatic data obtained from nine stations: Mafraq, Safawi, Rwaished, Azraq, Um El-Jumal, Ramtha, Dara'a of Syria, and Turaif and Guriat of Saudi Arabia (Figures 2 and 3).

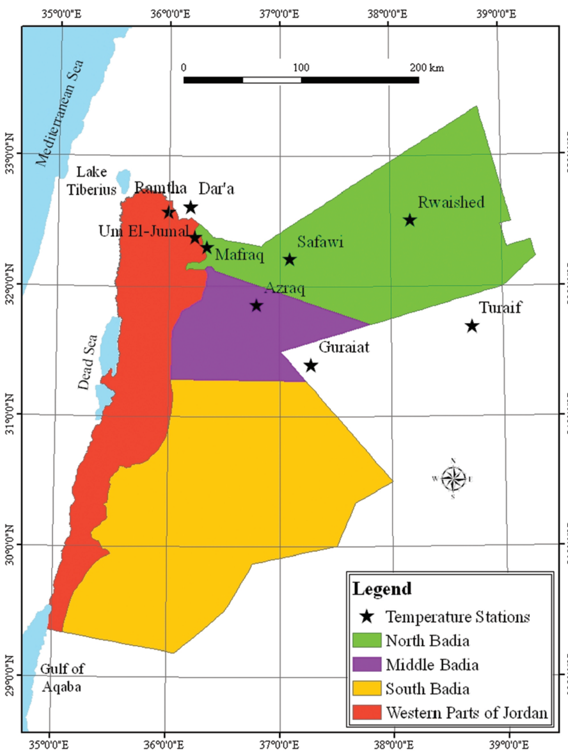

Figure 2. Monitoring stations that are selected to study temperature changes due to climate change.

A time-frame selected for the stations was in the range of 27-40 years of data covering the period 1972–2012. The data included daily rainfall and daily temperature. Processing of the data starts by calculating the monthly averages which are then plotted against historical records of atmospheric carbon dioxide in order to come up with plausible correlations and regression equations. In order to understand how air temperature and precipitation respond to the variation of atmospheric carbon dioxide, meteorological data are analyzed using IPM SPSS Version 19.0 (IBM Corp., 2010).

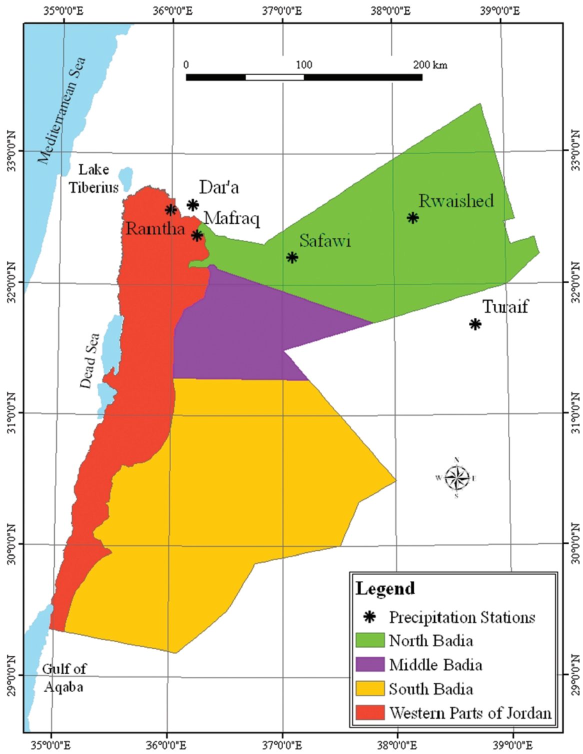

Figure 3. Monitoring stations that are selected to study precipitation variation due to climate change.

4.3. Air Temperature

The variations of air temperature at the study area are illustrated in Figures 4 through 12. It is evident that the air temperature is increasing at the nine stations. Figures 13- 21 illustrate the relationship between the mean concentration of atmospheric carbon dioxide and the mean annual air temperature at the nine stations. These Figures also show the projected air temperature at year 2050 based on the assumption that atmospheric carbon dioxide will continue to increase at its current incremental rate. It is evident that the increase in the abundance of atmospheric carbon dioxide leads to air temperature rise.

The correlation between the annual air temperature and the mean concentration of atmospheric carbon dioxide is utilized to forecast future air temperatures at North Jordanian Badia by deploying the linear regression approach which is available in the SPSS statistical package. Meteorological data for the years 1984-2010 were considered. The slope of the constructed regression line is used to predict future air temperatures. It is projected that average air temperature will increase by about 2-3°C at the nine stations by year 2050.

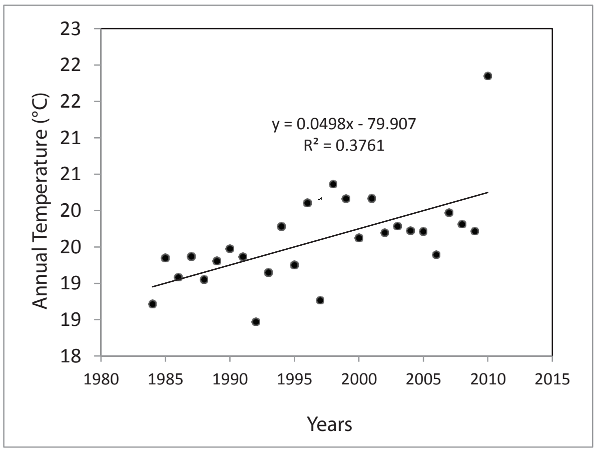

Figure 4. Average annual surface air temperature for Safawi station during the time period 1984-2010

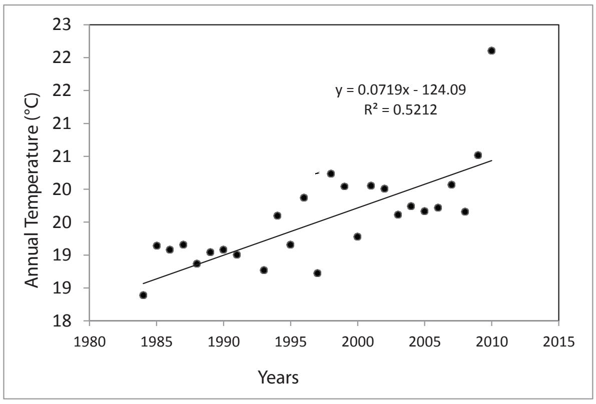

Figure 5. Average annual temperature for Rwaished station during the time period 1984-2010

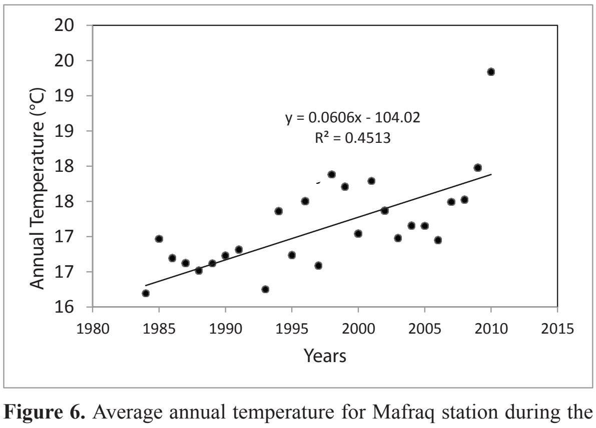

Figure 6. Average annual temperature for Mafraq station during the time period 1984-2010

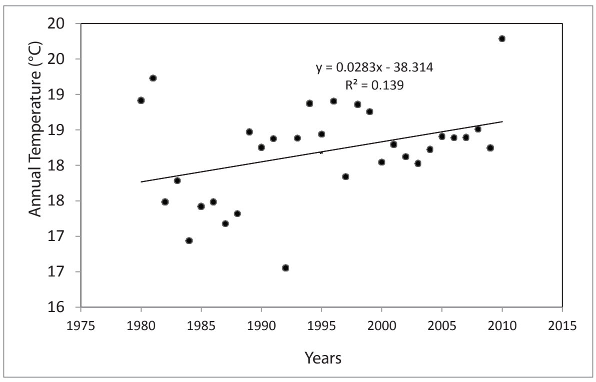

Figure 7. Average annual temperature for Um El-Jumal station during the time period 1980-2010

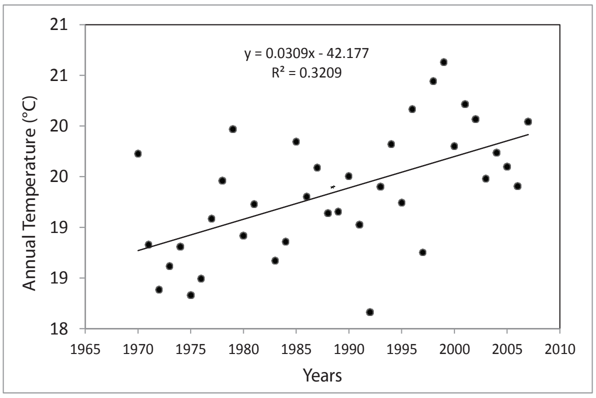

Figure 8. Average annual temperature for Azraq station during the time period 1970-2007

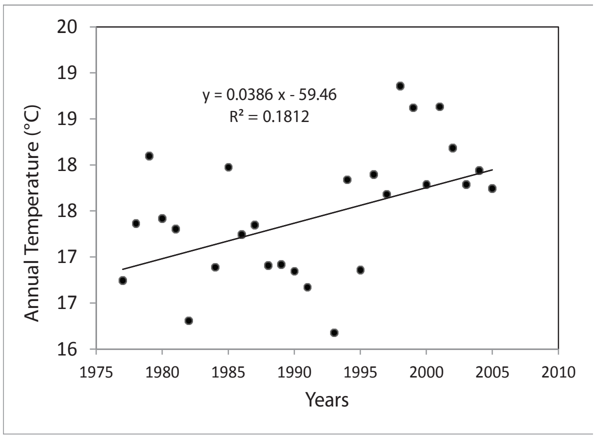

Figure 9. Average annual temperature for Ramtha station during the time period 1977-2005

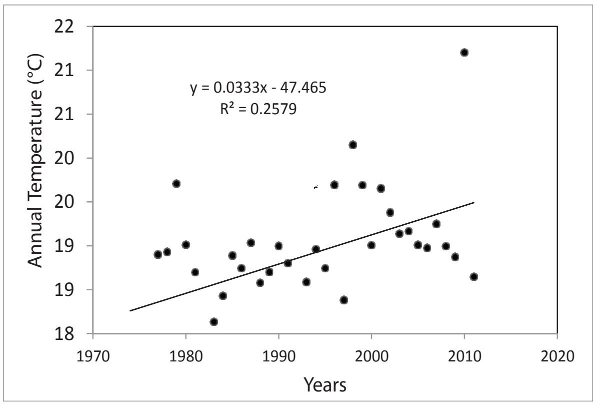

Figure 10. Average annual temperature for Turaif station during the time period 1974-2011

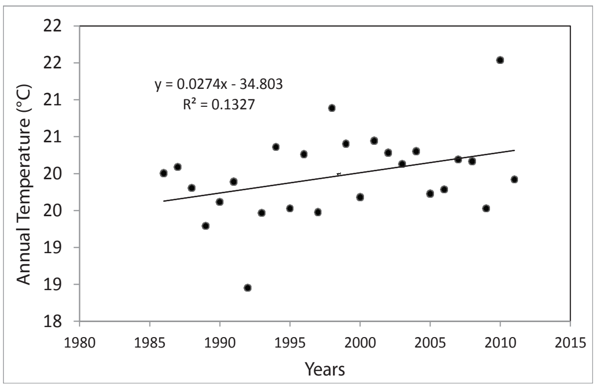

Figure 11. Average annual temperature for Guriat station during the time period 1986-2011

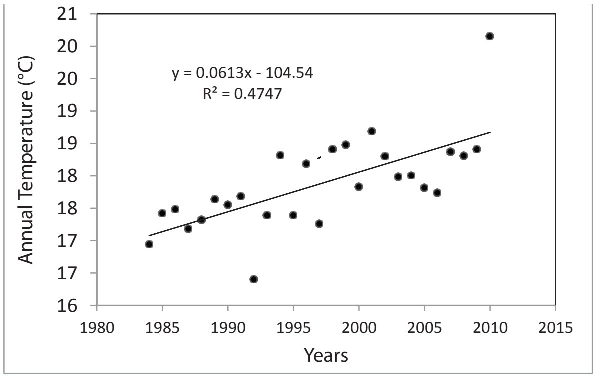

Figure 12. Average annual temperature for Dara'a station during the time period 1984-2010

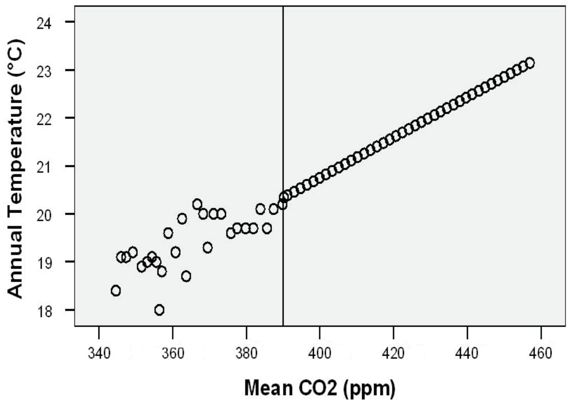

Figure 13. Projected air temperature at Rwaished in year 2050 based on presumed global CO_2 concentration

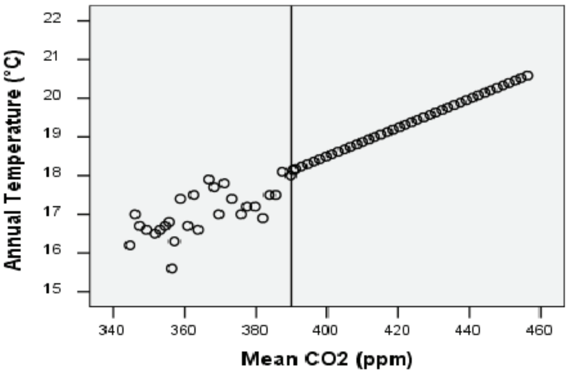

Figure 14. Projected air temperature at Mafraq in year 2050 based on presumed global CO_2 concentration

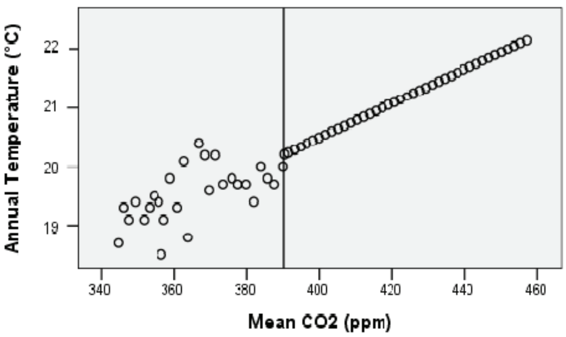

Figure 15. Projected air temperature at Safawi in year 2050 based on presumed global CO_2 concentration

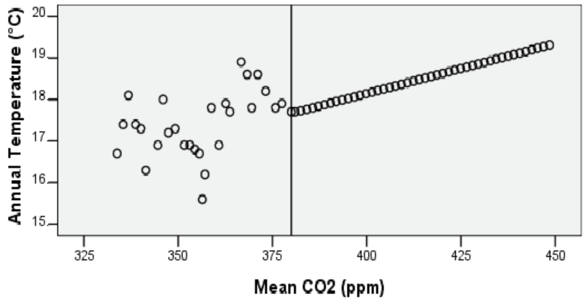

Figure 16. Projected air temperature at Ramtha in year 2050 based on presumed global CO_2 concentration

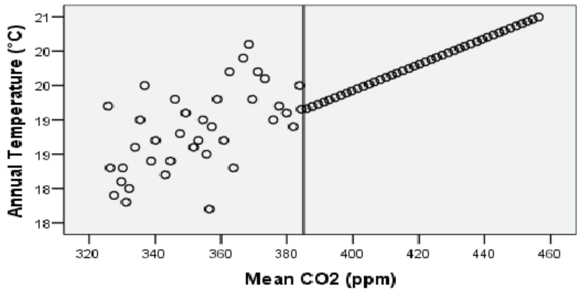

Figure 17. Projected air temperature at Azraq in year 2050 based on presumed global CO_2 concentration

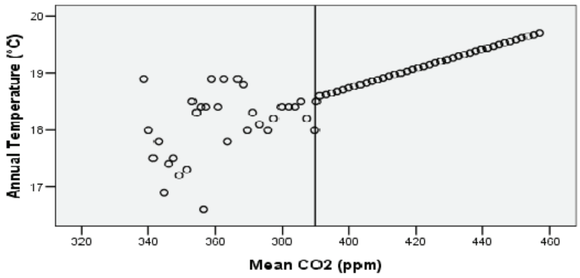

Figure 18. Projected air temperature at Um El-Jumal in year 2050 based on presumed global CO_2 concentration

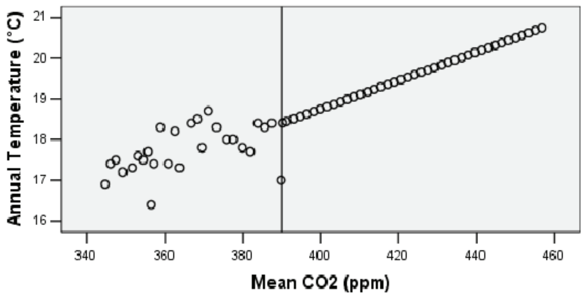

Figure 19. Projected air temperature at Dara'a in year 2050 based on presumed global CO_2 concentration

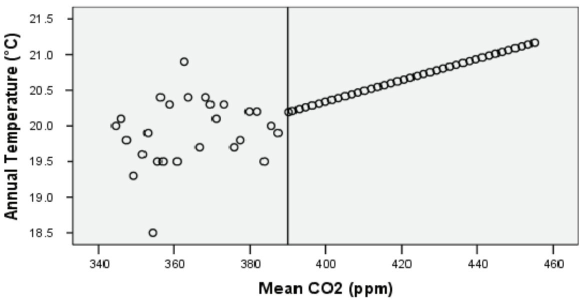

Figure 20. Projected air temperature at Guriat in year 2050 based on presumed global CO_2 concentration

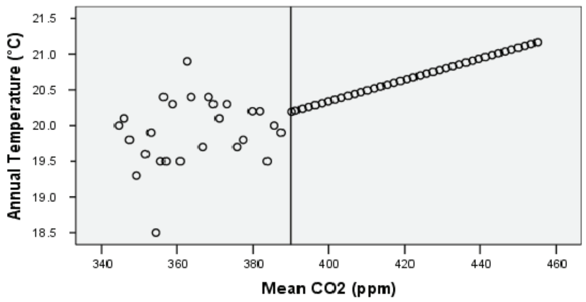

Figure 21. Projected air temperature at Turaif in year 2050 based on presumed global CO_2 concentration

4.4. Annual Precipitation

Figures 22-27 depict the variation of the annual precipitation at the nine stations. The charts reveal a decreasing trend in the annual precipitation at the North Jordanian Badia, but deriving sound conclusions or quantifying the annual decreasing rate is not feasible due to the high fluctuation in the precipitation data. Changes in precipitation due global warming may have severe implications on water resources in arid zones. Hydrological variability in a catchment area is influenced by the variations in precipitation over daily, seasonal, annual, and decadal time scales. Flood frequency is affected by the changes in the year-to-year variability in precipitation and by the changes in short-term rainfall properties (such as storm rainfall intensity). The frequency of low or drought flows is affected primarily by changes in the seasonal distribution of precipitation, year-to-year variability, and the occurrence of prolonged droughts.

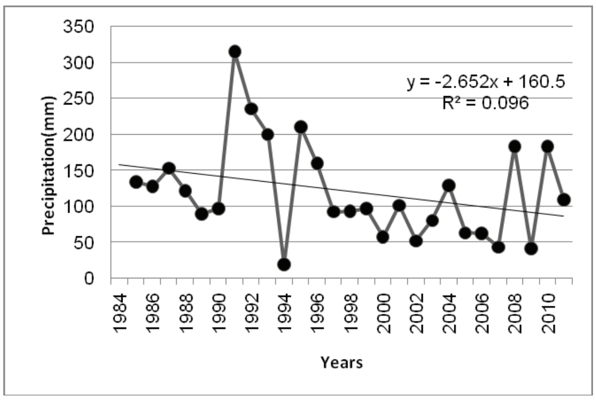

Figure 22. Annual precipitation for Safawi station (1985-2011) and the regression equation

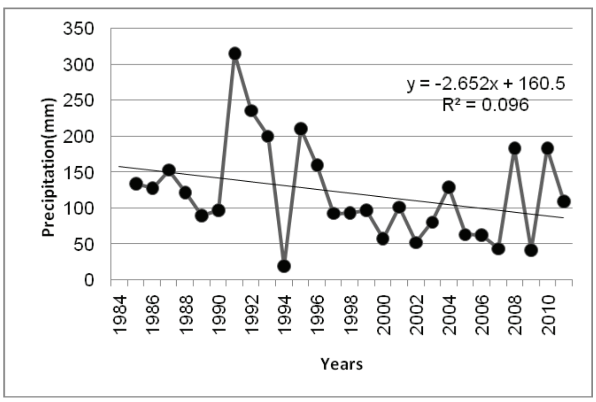

Figure 23. Annual precipitation for Rwaished station (1985-2011) and the regression equation

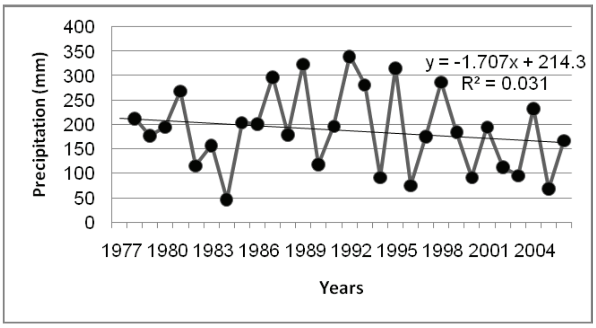

Figure 24. Annual precipitation for Ramtha station (1977-2005) and the regression equation

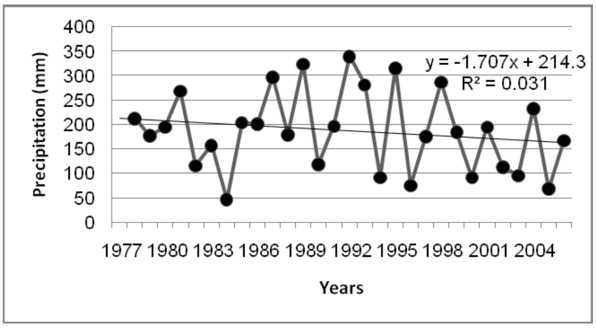

Figure 25. Annual precipitation for Mafraq station (1984-2011) and the regression equation

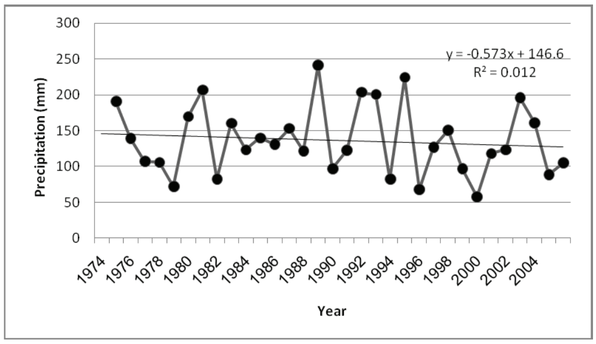

Figure 26. Annual precipitation for Turaif station (1975-2007) and the regression equation

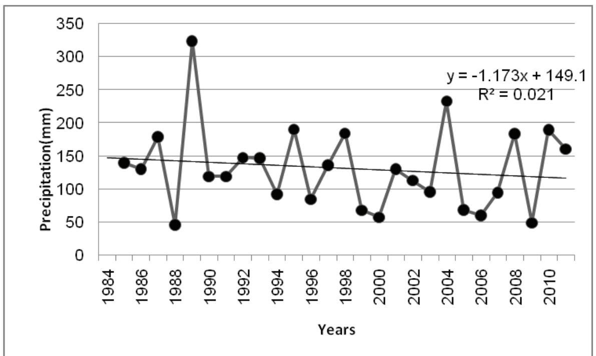

Figure 27. Annual precipitation for Dara'a station (1985-2011) and the regression equation

5. Summary and Conclusion

Northern Badia represents about 29 percent of Jordan's territory. It receives an annual rainfall of less than 200 mm and has general characteristics of seasonal contrasts in temperature with high variations in rainfall within and among years. Despite the low levels of rainfall in the northern Badia, the area constitutes an important source of grazing for livestock breeders. It is the source of livelihood for nomadic, semi-nomadic and settled communities that largely depend on raising livestock for a living. In addition to indigenous people, northern Badia hosts several Syrian refugee camps including Al-Zaa'tary.

The climate change will significantly affect the sustainability of water supplies in the Badia in the coming decades. The amount of water available and its quality will likely decrease, which will impact people's health and food supplies. These harsh conditions require local authorities and researchers to cope up with emerging crises associated with climate change. Thus, this study attempts to tackle this important issue by identifying changes in air temperature and precipitation, which are believed to be the two important indicators of climate change.

The air temperature and the annual precipitation for the nine stations in the northern Jordanian Badia and the neighboring countries were employed to detect the changes that are attributed to climate change. The Statistical Package for Social Sciences (SPSS) is deployed to come up with correlations that would project future values of air temperature and annual precipitation at the nine stations considered in the present study. Our findings revealed that while air temperature is increasing in the northern Jordanian Badia, annual precipitation is decreasing there. The pattern of the increase in the air temperature has been relatively uniform in the last 25 years. The annual precipitation data show a decreasing trend by up to 2.6 mm per year.

Acknowledgment

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Volumetric and landscape-ecological diachronic analysis of a historical artificial water reservoir Evička in Slovakia

Daniel Kubinský[1]*, Karol Weis[2], Milan Lehotský[3], Jakub Fuska[4], Pokrývková[4]

[1]Department of Biology and Ecology, Faculty of Natural Sciences - Matej Bel University, Tajovského, Banská Bystrica, Slovakia.
[2]Department of Geography, Geology and Landscape Ecology, Faculty of Natural Sciences - Matej Bel University, Tajovského, Banská Bystrica, Slovakia.
[3]Institute of Geography, Slovak Academy of Sciences, Štefánikova 49, Bratislava, Slovakia.
[4]Department of the Landscape Engineering, Horticulture and Landscape Engineering Faculty, Slovak University of Agriculture, Hospodárska, Nitra, Slovakia.

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Abstract

The present study focuses on the analysis and evaluation of the changes in the retention volume of the water reservoir Evička, the ecosystems of littoral, sublittoral and profundal zone as well as the changes in the land cover of the riparian zone and reservoir basin. The changes in reservoir volume were determined on the basis of a comparison of the actual bottom's topography, acquired through field surveying with the bottom's topography from the maps for a 40-year period (1971-2011). The volume of the sediments deposited in the water reservoir Evička for given period is 10917 m^3. The changes in the landscape structures of riparian zone and reservoir basin, identified on the basis of the analysis of aerial measurement pictures, orthophotomap and field survey, were evaluated for the period of 1949-2012, i.e., 63 year. It is evident from the analysis of the landscape structure changes in the whole reservoir basin that the area of developed surfaces increased by 11.2% and the surface area of water reservoir Evička decreased by 1165 m^2 during that period. We interpret these facts as the result of a negative anthropogenic effect, mainly by building activity within the reservoir basin and near the water reservoir. At the same time, the contribution presents possible measures for the management of water reservoir Evička and its surroundings.

Keywords: bottom bathymetry, lake ecosystems, riparian zone changes, reservoir basin development, siltation

1. Introduction

The erosion and sedimentation processes occurring in the reservoir basin cause the silting of water reservoirs, resulting in the spatial change in the morphology of their bottom's topography and thus changes in their thermal stratification and zonation. They cause a range of negative consequences, the most serious of which are the loss of usable volume, the gradual silting and the damage to manipulation devices of reservoir, causing changes in the biological and ecological quality of water and leading to the a gradual perishing of water reservoirs (Ahmed & Sanchez, 2011; Pradhan et al., 2011). They also significantly affect many organisms living in the water environments and cause the changes in their biotopes. The issue of sedimentation is current in many countries worldwide (Childs et al., 2003; Boddy & Ganske, 2005; Jordan et al., 2005; Kress et al., 2005; Ceylan et al., 2011). In the Slovak Republic, the Water Research Institute has been concerned with this issue for many years. Riparian zone as a three-dimensional entity of the interaction of aquatic and terrestrial natural systems is a specific part of water reservoirs (Gregory et al., 1991; Cebecauerová and Lehotský, 2002). It is often referred to as shore or near-river buffer zone (Malanson, 1993; Hupp and Osterkamp, 1996). The riparian zone has numerous functions (Hansen et al., 2010) that are important with regards to the sustainable development of water bodies and that need to be studied and monitored. This zone participates in improving the quality of water, i.e., it reduces the excessive supply of nutrients and contaminants from the surroundings (slopes, roads, fields, etc.), it reduces the erosion of shores and the supply of sediments, it increases the biodiversity, auto-regulates and optimises the structure and composition of its floral and faunal societies in an ecologically natural way. The present contribution's objective is the comparison and evaluation of spatial changes in the ecosystems of littoral, sublittoral and profundal zone as well as changes in the riparian zone and the morphometry of the topography of water reservoir Evička's bottom.

2. Site of the study

The water reservoir Evička is located in the cadastral area of Štiavnické Bane municipality near Banská Štiavnica (Fig. 1) and together with other water reservoirs around Banská Štiavnica is on the UNESCO World Heritage list. The water reservoir's origin dates before 1683 (Hydroconsult, 1991). The water reservoir's basin with the catchment boundary of 5.169 m has the total surface area of 1.370 km^2. Evička is the last stage of the cascade of water reservoirs Bakomi, Vindšachta, Evička. The smaller water reservoir Krechsengrund is part of

* Corresponding author. e-mail: posta@dkubinsky.sk

the reservoir basin as well, but it is not hydrologically bound with the higher lying water reservoirs.

Figure 1. Location of the water reservoir Evička within the Slovak Republic

3. Materials and methods

3.1. Assessment of storage capacity changes

When comparing the changes in the relief of Evička's bottom we proceeded with the analysis methodology of water reservoir Ružín (Pauk et al., 1997) and water reservoir Klenovec (Kočický et al., 2002) in Slovakia. This methodology was selected also for other water reservoirs in the Banská Štiavnica, Soovakia surroundings, e.g., in the research of Halčiansky tajch (Kubinský and Weis, 2011), Belianskeho (Kubinský and Weis, 2012), and Bakomi (Kubinský and Weis, 2013). The field research was executed on October 14, 2011. For an accurate depth measurement, the echosoundingdevice Humminbird 717 with a GPS device was used. The sonar uses a dual-beam probe 20° or 60° with the frequency of 200 & 83 kHz. The accuracy of sonar depth measurement, declared by the manufacturer, is ±10 cm, the declared accuracy of location measurement with the external 50-channel GPS antenna is ±100 cm. The device was placed on a boat, GPS recorded the location of every measured point, sonar measured the depth of bottom.

To eliminate the systematic error, control reference measurements with levelling staff, with flat base, were done during the measurement. The depth measurement only with the levelling staff without the use of sonar is difficult to implement into practice, mainly in depths over 5 meters, due to the stabilisation of the vessel on the surface and maintaining the vertical position of the levelling staff. Some of the already analysed water reservoirs were draw-down after the measurement due to the reconstruction of the dam by the Slovak Water Management Enterprise. The accuracy of the measurement of selected points was re-verified with the method of geometric levelling in the measurement accuracy level AL (Accurate levelling). The accuracy of results from the sonar device was determined by this verification to ± 3 cm.

The measured depths were converted to the absolute height above mean sea level of the bottom. The conversion was set on the basis of the difference of the known height of water level on the day of measurement. The absolute height above mean sea level of the water surface was set by the difference against the spot height of the safety spillway edge. At the time of measurement, the absolute height of the water reservoir's surface was 664.41 m a. m. s. l. The necessary data were provided by the office of Slovak Water Management Enterprise. The absolute height above mean sea level of the measurement point was derived after the subtraction of the measured depth from the height above mean sea level of the water surface. The position of measured points was converted to coordinates of the JTSK (Unified trigonometric cadastral network), Křovák's projection. In this way we acquired the first set of input data for modelling the actual topography of the water reservoir's bottom.

The input data sets for the elevation model 1971 were created as the vectorisation of contour lines of the historical map called "Evička Rybník - Štiavnické Bane" in the 1:10000 scale. The contour map was scanned in 300 DPI resolution and converted into digital TIFF format. The vectorisation of contour lines was done in the R2V software environment. Each contour line was assigned an information on height above mean sea level (Z coordinate) and the data were subsequently exported into a*.shp file. This file was later georeferenced into JTSK, Křovák›s projection. The georeferencing was done in the ArcGis software with the Spatial Adjustment module. As graphic data with known coordinate system were used the aerial images (Eurosence, 2006) and also several control points acquired by the field measurement with manual GPS. Easy to identify items, such as the location of service building on the dam, plotted buildings, edges of the dam, etc. were selected and used on both sources. The second input set of data for modelling the contemporary topographyof the water reservoir Evička›s bottom, i.e., the model representing the state from 1971, was acquired in this way. 3D models, describing the situation for both timelines, were generated and visualized for the years 1971 and 2011 (Figs. 2 and 3) in the Surfer 8 software environment (Golden Software, Colorado, USA). We used the Kriging interpolation method with the 2×2 m raster unit size for the generation of models. The changes in the bottom›s topography provided an information basis for the identification of ecologically interpretable changes in the upper layer of littoral, sublittoral zone and the deepest profundal zone of the water reservoir›s bottom (Hartman et al., 2005).

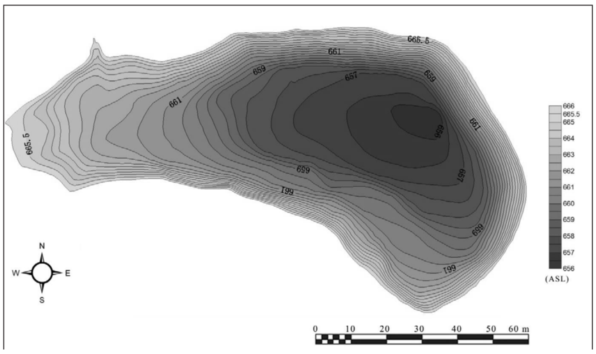

Figure 2. The detail of the topography of water reservoir Evička's bottom (condition in 1971)

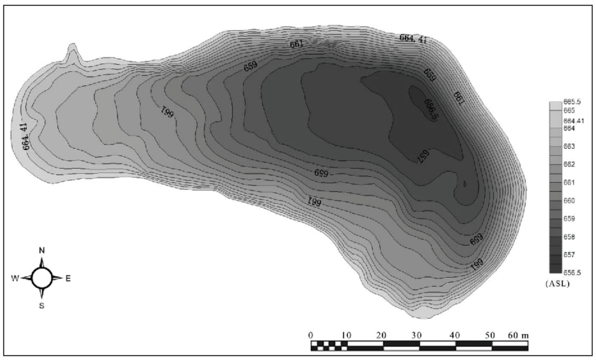

Figure 3. The detail of the topography of water reservoir Evička's bottom (condition in 2011)

3.2. Assessment of the reservoir basin and ecosystems changes

The changes in the affected ecosystems in the water reservoir and landscape structures in the riparian zone were processed in the ArcGis software environment. The riparian zone was defined as 20-meter wide surroundings or buffer from the shoreline. Through the interpretation of orthophotographfrom 2006 with subsequent completion of data by field inspection as the actual status (2012) and the regressive interpretation of aerial black and white pictures from 1949, we created a map of the land cover of the area for both timelines (1949 and 2012). The evaluation of the riparian zone structure was done for 1949 (Fig. 4) and for 2012 (Fig. 5). Through analysis and synthesis of supporting results (changes in bottom's topography and riparian zone), we proceeded to the selection of the changes in ecosystems in the water reservoir Evička (Fig. 6).

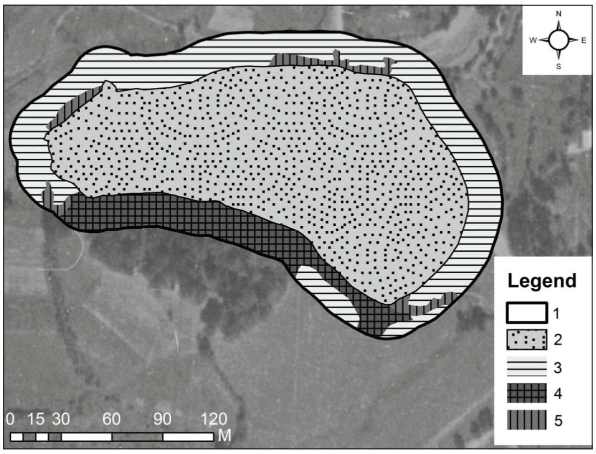

Figure 4. The situation of the riparian zone in 1949 (© Copyright Topografický ústav Banská Bystrica)
Legend: 1) the boundary of the riparian zone, 2) water surface, 3) stable grassy vegetation, 4) tree vegetation, 5) bushes

Table 1. Calculation of the volume of sediments deposited in the water reservoir Evička

Interpolation method	Area [m^2]
Trapezoidal Rule	10,921
Simpson's Rule	10,916
Simpson's 3/8 Rule	10,913

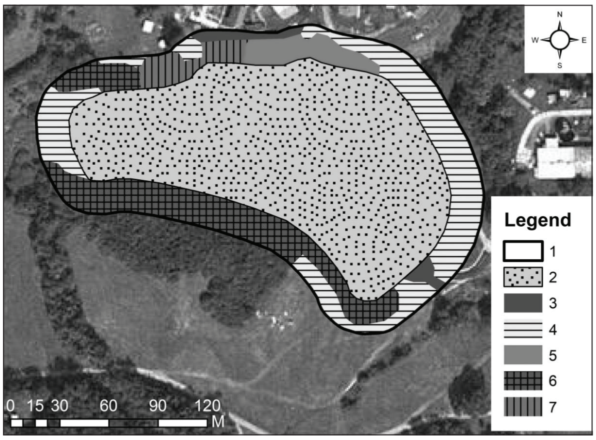

Figure 5. The situation of the riparian zone in 2013 (© Eurosence, 2006)
Legend: 1) the boundary of the riparian zone, 2) water surface, 3) developed areas, 4) stable grassy vegetation, 5) scattered trees, 6) tree vegetation, 7) bushes

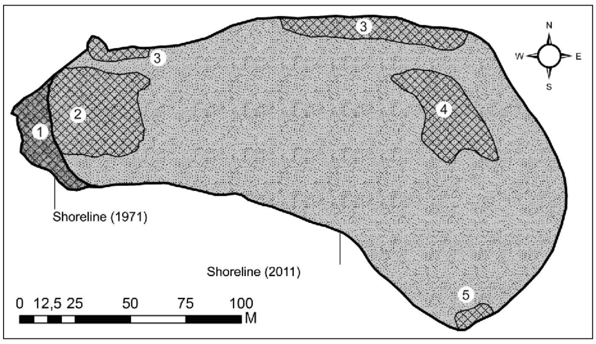

Figure 6. Changes in the water reservoir Evička's ecosystems

The landscape structures of the reservoir basin were mapped in the ArcGis software environment. Through the interpretation of orthophotograph from 2006 with subsequent completion of data by field inspection as the actual status (2013) and the regressive interpretation of aerial black and white pictures from 1949, we created a map of the land cover of the area for both timelines (1949 and 2013). Given the fact that the water reservoir Evička was reconstructed in 2013/2014 to secure and increase the safety of the dam, this water reservoir was drained at the time of writing of this contribution and therefore the accurate geodetic measurement of sediment distribution was possible. On the basis of field inspection, the boundaries of accumulated sediments were visually determined; their exact location was determined by a total station placed on the dam's crest.

4. Results

4.1. Changes in Volume and Bottom's Topography

We acquired the following models with computer visualisation of the bottom's topography. The greatest change in the topography occurred in the area of the greatest depth (Fig. 3). The course of contour lines with the height above mean sea level of 657 m a. m. s. l. and 657.5 m a. m. s. l. is significantly modified and their outlines prove the shallowing of the water reservoir's central part by at least 60 to 80 cm. It proves that the significant part of deposited material is accumulated right in these parts. This happened despite that during the first reconstruction of the water reservoir Evička in 1993 the bottom sediments were partially removed to enable access and safe manipulation with the outlet device. Signs of sediment accumulation can be seen also in the western part of the water reservoir, in the direction towards the feeder from the higher located water reservoir Veľká Vindšachtská, where the S-shaped bend of a series of contour lines suggests the forming of double-sided symmetric benches with central, slightly meandering gully. In this space, the trough (erosive) bedding is dominant. This gully is functioning at the time of the long-term summer decrease of water level after the previous deficit of rainfall during subsequent episodic torrential rains. The second period, when this feeder gully is functioning, is spring, when after the winter decrease of the operating water level come either floods of water with higher energy during a sudden rise of temperature and a fast melting of ice and the strong flow erodes in this gully even under the ice or during the first strong spring showers, when the water reservoir's surfaces is not covered with ice.

Table 2. Surfaces of riparian zone's category

Surface category	Surface area [m^2]		Change of area [%]
	1949	2012	
Water surface	20,413	19,248	-5.7
Stable grassy vegetation	11,770	5,946	-49.48
Scattered trees	-	1,136	+100
Bushes	3,299	986	-70.11
Forest-like vegetation	11,770	4,873	-58.59
Developed areas	-	586	+100
Total	47,252	31,639	-33.04

The contour lines in south-southeast and mainly in the most eastern part of the water reservoir show the same nature, just with different origin of accumulations. Despite the sporadic but too poor water source existing in this part (probably a descending contact or talus spring), the fine-grain material is in the water reservoir distributed mainly through movements of the water mass in the prevailing direction of rippling. Also, a mild directional sorting out of grain fractions and the creation of slanting bedding, in places with the characteristics of ripples, corresponds with this.

The calculated differences in volume from the comparison of the condition of bottom's topography in the past and present, executed in the Surfer 8 environment with the use of three computational methods, are as follows:

- Given the standard deviation of all values is minimal ($\sigma = 4.04$), the resulting value was determined as an arithmetic average of all three calculations, i.e., 10917 m^3. This value represents the volume of sediments deposited in the water reservoir Evička's space for the time period of 40 years and represents a decrement in the water reservoir's overall storage volume by the given value (Fig. 13).
- To determine the changes in the water reservoir's bottom due to sedimentation, cross-sections were constructed every 32 meters; 7 profiles in total, A – G and one longitudal section, H, across the water reservoir in the east-west direction (Fig. 12) and maximum and average thickness of sediments and the standard deviation were evaluated (Table 5).

4.2. Changes in Reservoir Basin

In accordance with the analysis of landscape structure changes in the whole reservoir basin (Fig. 7 and Table 3), the amount of developed surfaces increased significantly by as much as 11.2%. The development conditioned by the adjustment of slopes and roads mainly on meadow and pasture surfaces has probably the greatest influence on the amount of sediments deposited in the water reservoir. The trend of gradual development and the change of the surroundings to urban area will probably continue also in future. Therefore, it is necessary to look for such water management measures that will focus more on capturing the sediments already before the entry into the water reservoir than on the reduction of their creation. It should be noted that there is no longer a water reservoir below the water reservoir Evička today. In the past, there was a water reservoir bottom Vindšachta approximately 500 m below in the direction of valley, but today it is completely filled up. The possible decrease in the amount of sediments with flushing the water reservoir could be considered, it would not mean the sediment transfer from the upper to the lower water reservoir. We assess the increase in afforestation in the reservoir basin by 14.5% positively. It concerns mainly fast-growing tree species. In the reservoir basin has occurred a significant reduction in the surface area of meadow vegetation from the original 66.5% of the overall surface area to 41.8%, whereas 13.17% of meadow vegetation was built up and changed to municipality's urban area and 20.85% of the surfaces were forested.

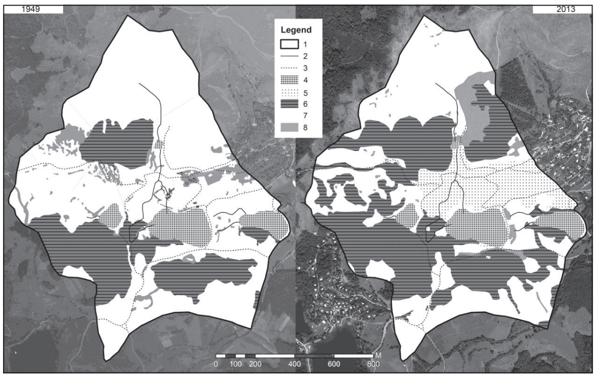

Figure 7. Changes in the water reservoir Evička's reservoir basin
Legend: 1) the boundary of reservoir basin, 2) roads, 3) streams, 4) water surface, 5) developed area, 6) forest vegetation, 7) meadows and pastures, 8) bushes

4.3. Changes in Riparian Zone and Ecosystems

By comparing the changes in the topography of water reservoir's bottom for the period of 1971-2012 (Figs. 4 and 5) and changes in the riparian zone for the period of 1949-2012 (2) as the element, development of which directly affects the water level, we selected the following parts within the water reservoir's area that were affected or modified during given time periods (Fig. 6):

1. The water surface from 1971 was transformed to a terrestrial ecosystem fully filled with soil, located

behind the shore line, due to sedimentation processes. Its land cover is represented by bushy vegetation, the substrate consists of fine sandy sediment but also spreading gravel for the winter maintenance of roads. Thus, the water ecosystem became a terrestrial one during the monitored period. Today, this part is overgrown with common reed (Phragmites communis) and fast-growing natural seeding tree species.

2. The area of significant shallowing, acquired through the comparison of 3D elevation models of the bottom. We expect the presence of fine mud sediments and due to a more significant decrease in depth also change in temperature and light regime.
3. The increase in the presence of the wood vegetation and the possibility of the organic mass falling into the water reservoir. The detritus can cause local short-term changes in the water's pH. The increase in shading did not occur due to the shore oriented to the north.
4. The deepest part of the water reservoir shrank and became shallower due to the silting and deposition of sediments. The deepest parts of the water reservoir are the environment for the wintering of cyprinids and therefore their changes and the gradual decrease of depth will affect mainly these species.
5. The area near the adjusted outlet gully of safety spillway. Because the outlet gully is the only outlet, we can expect the sedimentation of the finest material in its close surroundings due to the flow of water.

4.4. Changes in Thermal Stratification

Due to the erosion and sedimentation processes, the accumulation of material and the anthropogenic effect, changes also in the water reservoir's stratification occurred in the area of the water reservoir Evička. The stratification of the water reservoir Evička in 1971 and in 2011 and the surface areas of individual zones were evaluated (Figs. 8 and 9, Table 3).

Table 3. Changes in landscape structures in the reservoir basin (1949 – 2013)

Landscape structure category	Surface area [km²]		Proportion [%]		Change of area [%]
	1949	2013	1949	2013	
Meadows	0.911	0.574	66.5	41.8	-24.7
Forest	0.312	0.512	22.9	37.4	+14.5
Non-forest vegetation	0.071	0.057	5.2	4.1	-1.1
Developed area	0.003	0.156	0.2	11.4	+11.2
Water surface	0.073	0.071	5.3	5.2	-0.1
Total	1.370	1.370	100	100	0.00

The distribution of the sediments in the area of the water reservoir and the expected direction of their supply and subsequent accumulation was visualised (Fig. 10). Two sources of sediments can be observed, one in the western part of the water reservoir in the places of the feeder gully from upper water reservoirs and one in the southern side, where the transfer of sediments from surrounding slopes occur. The distribution of sediments is unequal due to a slight inclination in the bottom's topography. The sediments deposited from the western part do not have enough kinetic energy capable of their transfer over the bottom of this inclination and they are transported further towards the deepest parts of the water reservoir. The field survey at the drained water reservoir Evička's bottom has shown the occurrence of spreading material in the most western part. The sediments deposited from the southern part are re-deposited in the deepest parts and only a small part of it accumulates at the inclination's dam crest in the bottom's topography.

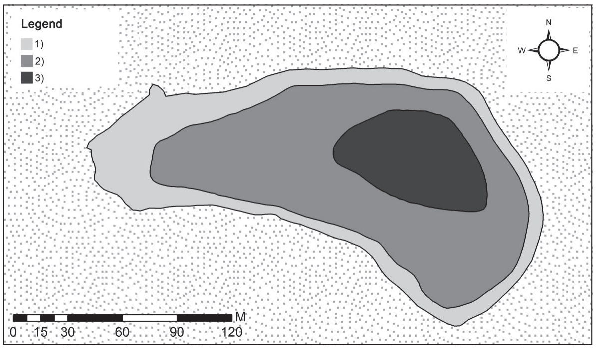

Figure 8. The stratification of the water reservoir Evička in 1971
Legend: 1) littoral zone, 2) sublittoral zone, 3) profundal zone

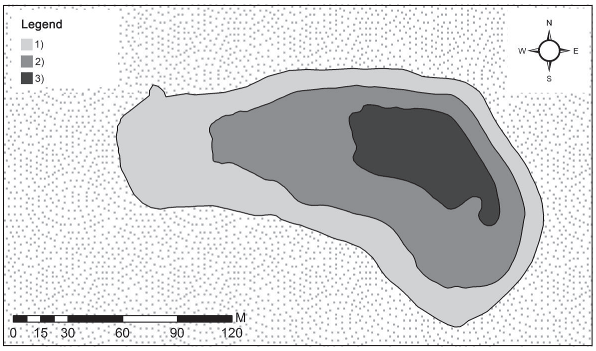

Figure 9. The stratification of the water reservoir Evička in 2011
Legend: 1) littoral zone, 2) sublittoral zone, 3) profundal zone

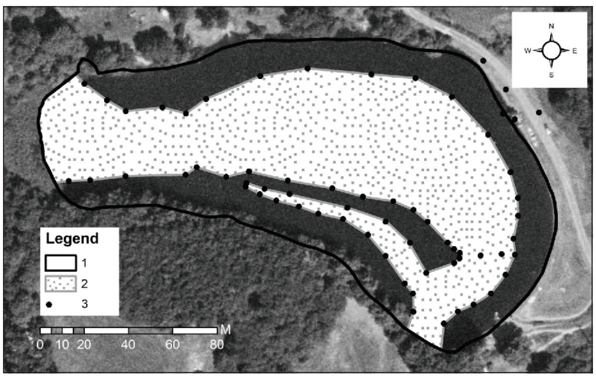

Figure 10. Distribution of sediments in the water reservoir's area
Legend: 1) Shore line in 2013, 2) the boundary of accumulated sediments, 3) topographical points

Table 4. The calculated surface areas of the water reservoir Evička's zones

Surface category	Surface area [m^2]		Change of area [%]
	1971	2011	
Littoral	4,830	7,384	52.87
Sublittoral	12,264	9,065	-26.08
Profundal	3,065	2,797	-8.74
Total	20,160	19,248	-4.52

Figure 11. View on the Evička water reservoir's bottom during reconstruction

Table 5. Sediment thickness and Sample standard deviation of cross sections

Section	Sediment thickness [m]		
	Max	Average	Standard sample deviation
A	1.17	0.75	0.44
B	1.09	0.64	0.95
C	1.27	0.56	0.90
D	1.31	1.1	0.87
E	1.42	1.5	0.89
F	1.21	0,57	0.85
G	1,40	1.2	0.40
H	1.31	0.59	0.32

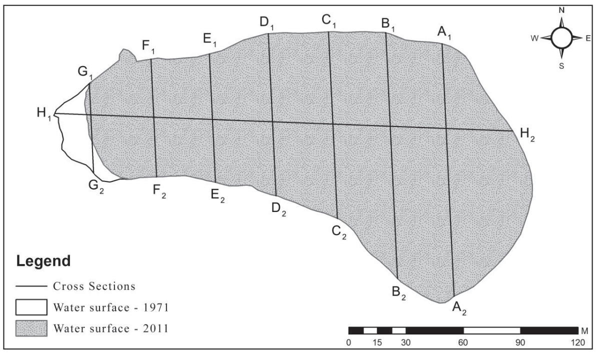

Figure 12. Location of selected cross section lines of water reservoir Evička

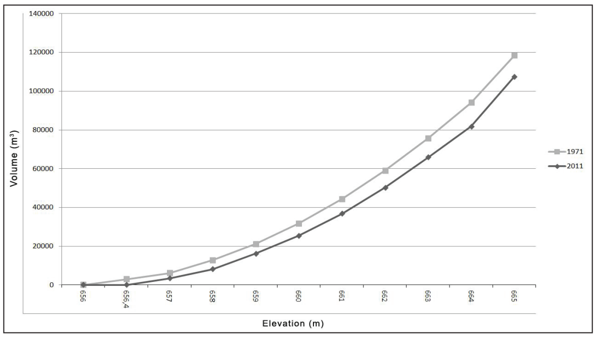

Figure 13. Figure 13. Volumes of water reservoir Evička

5. Discussion

The methodology of data collection using the ultrasound device and sonar proved to be sufficiently accurate, fast and economical. This procedure, with slight modifications, is also commonly used in studies at other locations (Dost and Mannaerts, 2008; Choiński and Ptak, 2009; Elçi et al., 2009; Hollister and Milstead, 2010).

In the results, we can see a negative effect of erosion and sedimentation processes on the changes in bottom's topography and the overall morphology of the water reservoir Evička's bottom, but also the changes in the landscape structure and ecosystems in the shore zone. The volume of sediments deposited in the water reservoir Evička for 40 years is 10917 m^3. Even despite the short time horizon we are not talking about extreme silting. For example, the water reservoir Alitnapa in Turkey was decreased by 33.4% for the period of 1967-2009 (Ceylan et al., 2011). The negative situation of silting of lakes and water reservoirs was described also in the neighbouring Poland, where 25 lakes in total has lost 9.9% of accumulation capacity over 50 years (Choiński and Ptak, 2009). The concentration of sediments at bottom outlet, frequently reaching the height of several meters (Kubinský and Weis, 2012), it can often lead to the loss of the device's function. The negative phenomenon is common also at other water reservoirs, e.g., the Dąbie lake in Polland, where over 2 meters of sediments were deposited over the years 1962-1996 (Wiśniewski and Wolski, 2005).

For the period of 22 years (1949-1971), the water surface area shrunk by 252 m^2 in total, the overall decrement of water surface area for the period of 40 years (1971-2011) is 912 m^2. That means that the water surface area of the water reservoir Evička has shrunk by 1.165 m^2 for the period of 63 years (1949-2012). This indicates the fact of a negative, mainly anthropogenic effect. The increased construction and building activity is typical mainly for past twenty years, whereas the construction adjustment and the construction itself are continuously nearing the water surface itself. As we can see by the comparison of landscape structures in the reservoir basin for the period of 1949-2013, the fact of increased development due to gradual expansion of the Štiavnické Bane municipality is obvious. At locations with predominantly meadow and pasture surfaces, new buildings gradually emerged, this factor is also conditioned by the adjustment of slopes and construction of access roads. The importance of the analysis of changes in land cover in relation to the silting of water reservoirs was described also in other locations (Newman et al., 2009). It is evident from the results of these works that the changes in the use of land and land cover lead to the understanding of the sedimentation mechanisms throughout the whole reservoir basin.

As it is noted on the geological map (SGÚDŠ, 2013), the majority of the reservoir basin's surface lies on predominantly loam-stony (inferiorly sand-stony), deluvim and detritus deluvial sediments. It is a subsoil that is unstable to water erosion, it is eroding very quick when uncovered and the material of sand-loam nature is subsequently transported with surface flow. The Evička's reservoir basin includes 3 other water reservoirs capable of accumulation of the sediments (Bakomi, Vindšachta, Krechsengrund), but the micro-reservoir basin belonging only to the water reservoir Evička lies in a significant part on the mentioned subsoil of deluvial sediments.

The accumulation of sediments is a serious problem not only in Slovakia. Over 45 years (1966-2011), the artificial lake Velika Dicina in Serbia accumulated 18.750 m^3 of sediments (Ristic et al., 2013). The authors see as the main cause of the adverse condition the anthropogenic effect in the reservoir basin.

The negative trend of building and development near the water surface itself is not exceptional. We can encounter it at other water reservoirs in the vicinity of Banská Štiavnica (Kubinský et al., 2014). The analysis of the development of erosion and sedimentation processes is key in designing of the management procedures in the whole interest reservoir basin (Ambers, 2011; McAlister et al., 2013), it enables to predict the future development (Wiśniewski and Wolski, 2005). Abroad, we can encounter also the division of reservoir basins into zones with different management approach (Lin et al., 2000). Given the relatively small reservoir basin with two other water reservoirs, we did not divide the reservoir basin any further.

The results of stratification show that the changes occurred also in individual zones, in their surface areas. These are characterised by variable ecological conditions (water temperature, lighting, water density, the circulation of oxygen, CO_2, ...) and subsequently by species variability. The erosion of water reservoir's uncovered shores and the subsequent flush of terrigenous material into the littoral environment, together with the annually accumulated layer of decomposing organogenous detritus (the cast of leaves and needles, organic remains of water organisms and plants), contribute to a significant degree to slow and gradual eutrophication.

We can encounter this type of native biotope devastation mainly in smaller and more shallow water reservoirs (for example, in Bakomi, Klinger, Belianska reservoirs), but even the larger water reservoirs, where the regular removal of deposited sediments ceased over the years (for example, in the mouth of the Halčianska water reservoir feeder) or where the fixation of ecologically adverse condition occurs through gradual decrease in flow rates in feeders, are not an exception. For these water reservoirs only minimal exchange of water in the water column (often made impossible also by the non-functioning of bottom outlet) is typical, thus gradual eutrophication and the silting of the water reservoir with fine-grain sediments occurs (for example, in Ottergrund, Krechsengrund, Brenneštôlnianska, Červená studňa or Komorovské ponds). This fact also refers to actuality and the importance of systematic research also on other water reservoirs and it also proves the fact that adverse development occurs in water reservoir. In general, we summarised the causes to the devastated system of trenches, the decrease in the flow rate of feeders with excessive consumption and deflection already before the inflow to the water reservoir, the non-functioning of bottom outlet devices, the absence of sump caissons for sediments in feeders' mouthings. Last but not least, it concerns also the uncovered shores of the water reservoir, the flushing of the eroded, medium to fine-grain material (soil, sand, loam, clay) with the surface rainwash, the decomposition and accumulation of organogenous detritus, the insufficient prevention of enormous macrophyte development, mainly the submersive vegetation, the gradual overheating of the water reservoir due to draining the heated layer through the surface spillway instead of draining the colder "bottom" water. The water reservoir Evička is undergoing the second repeated phase of general repair in 2013-2014. The process of the reconstruction of water reservoirs in Banská Štiavnica area is executed by SVP, š.p., which is responding to the fact that even though the water reservoir Evička was among the the first reconstructed water reservoirs after 1989, the non-functioning of the bottom outlet device in the third, last stage of the Bakomi – Veľká Vindšachtská – Evička cascade was a serious issue. The water reservoir Bakomi, as the first stage of the mentioned cascade, shows only slight supply of sediments for the same period of 41 years (Kubinský and Weis, 2013). We assume that several of the described adverse effects will be gradually eliminated after the successful completion of the reconstruction of outlet device, the dam and the handover of this water reservoir into use.

Conclusion

The present work points out the changes in the water reservoir Evička's ecosystems, using diachronic analysis of its bottom's topography and the riparian zone. The changes in bottom's topography are conditioned mainly by erosion and sedimentation processes and the subsequent accumulation of sediments in the water reservoir. The changes in riparian zone have direct effect on multiple factors that condition the temperature and light regime. We have selected several changed ecosystems in the area of the water reservoir through the synthesis of both main factors, i.e. the changes in topography and in the landscape structure of the riparian zone. Evička is not only a technical monument, recorded on the UNESCO list, but it is important to see it as an ecosystem as well that contains in a relatively small space a confined population of organisms and in which relatively important changes occur over the course of time, as the results of the contribution indicated.

Acknowledgement

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Assessment of Solid Waste Management in Lokoja, Nigeria

Musilimu Adeyinka Adetunji*[1], Tolu Isaac Atomode[1], Ismaila Okino Isah[1]

[1]Department of Geography, Faulty of Arts & Social Sciences, Federal University Lokoja, Kogi State Nigeria

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Abstract

Urbanization has constituted a great environmental challenge to human existence in all countries of the world. The situation in urban centers of developing economies is more serious and has become unbearable because the access to basic necessities, such as portable water and functional health facilities, is very poor. To worsen the matter, in some of these cities, there is a delayed and uncoordinated waste disposal system which makes many people vulnerable to the outbreak of diseases. It is against this background that the present study is designed to assess the waste management system in the rapidly developing city of Lokoja which is located in the north central part of Nigeria. Basically, primary sources of data were employed in this research to collate information about waste disposal and its health implications on the inhabitants of the city. An average of forty structured questionnaires was distributed to the heads of households in each of the three residential densities identified in Lokoja on how the waste is managed in the city. Descriptive and inferential statistics were employed to analyze the data collected. The findings revealed that 64.6% of residents in Lokoja burn the waste generated in their household; 20.8% dump their waste along the roadsides for public waste disposal vehicles to collect and dispose of them at the approved waste disposal site located in the city suburb. Approximately, 16.8% of the residents who live close to the trenches of streams and erosion channels dispose their waste in the water bodies for onward transmission to bigger water bodies like Meme River and the River Niger. This impedes the free flow of drainage water and consequently results in the flooding of the roads especially during heavy down pour in the Metropolis. The nonchalant attitude of people towards better waste management has therefore resulted in various forms of pollution including air and water pollution which is inimical to human health. The present study concludes that there is need for public enlightenment and campaign on modern methods of waste management in Lokoja and other cities in Nigeria.

Keywords: Health, Waste, Transport, Environment and Planning.

1. Introduction

According to Nwigwe (2008), "refuse disposal is one of the major environmental problems that developing countries are faced with. Health hazard, traffic congestion, unsightliness, unpleasantness and blockage of drainages are some of the problems caused by lack of efficient waste management practice in Nigeria." Solid waste disposal is treated with levity in developing countries of the world, most especially in Nigeria which has experienced high rate of urbanization within the last four decades. The nonchalant attitude of people in African countries toward modern methods of waste disposal has posed serious environmental health challenge to human existence in their natural environment (Afangideh et al., 2012). Meanwhile, one of the aspirations of the western world is to achieve sustainable environment.

According to Mansoor et al. (2005), "proper solid waste disposal is an important component of environmental sanitation and sustainability." A sustainable environment and improved waste management offer opportunities for income generation, health improvements and reduced vulnerability. This could hardly be attained in some of the developing countries, most especially in Nigeria because of non- readiness, uncoordinated and laissez faire attitude toward better ways of solid waste disposal methods in spite of their high rate of urbanization and growth in commercial and industrial activities (Afangideh et al., 2012). The situation of solid waste disposal methods in some of the Nigerian cities lives more to be desired as garbages of waste generated litter all nook and cranny of the towns and cities.

In a study on municipal solid management in China, Dong et al. (2010) report that the amount of municipal solid waste generate increased tremendously from 31.3 million tons in 1980 to 212 million tons in 2006, and the waste generation rate increased from 0.50 kg/capita/day in 1980 to 0.98 kg/capita/year in 2006. According to them, the waste composition in China is dominated by the concentration of kitchen waste in urban solid waste which accounted for 60% of the waste stream. The report on municipal solid waste of Dong et al. (2010) in China further stressed that the total amount of municipal solid waste collected and transported was 148 million tons in 2006, of which 91.4% was landfilled, 6.4% was incinerated and 2.2% was composted. The overall municipal solid waste treatment rate in China was approximately 62% in 2007. In 2007, there were 460 facilities, including 366 landfill sites, 17 composing plants, and 66 incineration plants. The report of Dong et al. (2010) was able to throw more light on

* Corresponding author. e-mail: maadetunji@yahoo.com

the waste generation and composition in the Asian continent most especially in China where the research was conducted.

Several studies conducted in different parts of the world, particularly in major urban centers in Europe and United States of America, show that the types of waste generated and management techniques vary with the level of civilization, industrialization and socio-economic well-being of the nation involved (Herbert, 2007). However, the solid waste generated from industrial products, such as polythene bags, plastics from beverages, electronic materials, broken bottles and empty cartons, constitute hidden places for vector diseases. Also, offensive odor emanating from dumping sites constitutes environmental risks to human health.

It is worrisome that much research on waste management has been conducted in Nigeria and other developing countries. However, some of the studies do not adequately examine the environmental impact of waste disposal methods on human health which is the main focus of this research. The principal objective of this study is to examine the methods of waste disposal and their associated health implications on the urban residents in Lokoja Metropolis. This will give city planners and other stakeholders a chance to develop appropriate database for proper sanitation in urban environment with the aim to reducing the risk of urban residents from being vulnerable to outbreak of diseases which is inimical to human health.

2. Study Area

Lokoja, the capital city of Kogi State, can be found between latitude 7⁰45’ 27.56’’ - 7⁰51’ 04.34’’ N and longitude 6⁰41’ 55.64’’ - 6⁰45’ 36.58’’ Eof the equator with a total land coverage of about 63.82 sq. km. (Adeoye, 2012). It is a former capital territory of the British Northern Protectorate under the leadership of Lord Lugard. According to Olawepo (2009), Lokoja became the headquarters of Kogi Local Government Area as far back as 1976 and was later made Kogi State capital in 1991. Since then, there has been a massive change in all activities of Lakoja, including its size, structure, population and other socio-economic development.

The city is located in the confluence of river Niger and Benue (See Figure 1). These two rivers serve as a driving mechanism for the movement of agricultural products from riverine areas of the state to Lokoja where a bulk of the population resides. Within the last three decades, Lokoja Metropolis, like many other urban centers in Nigeria, has witnessed a tremendous population increase. The phenomenal increase in the population over the years in the city has led to a high demand for goods and a resultant increase in waste generation.

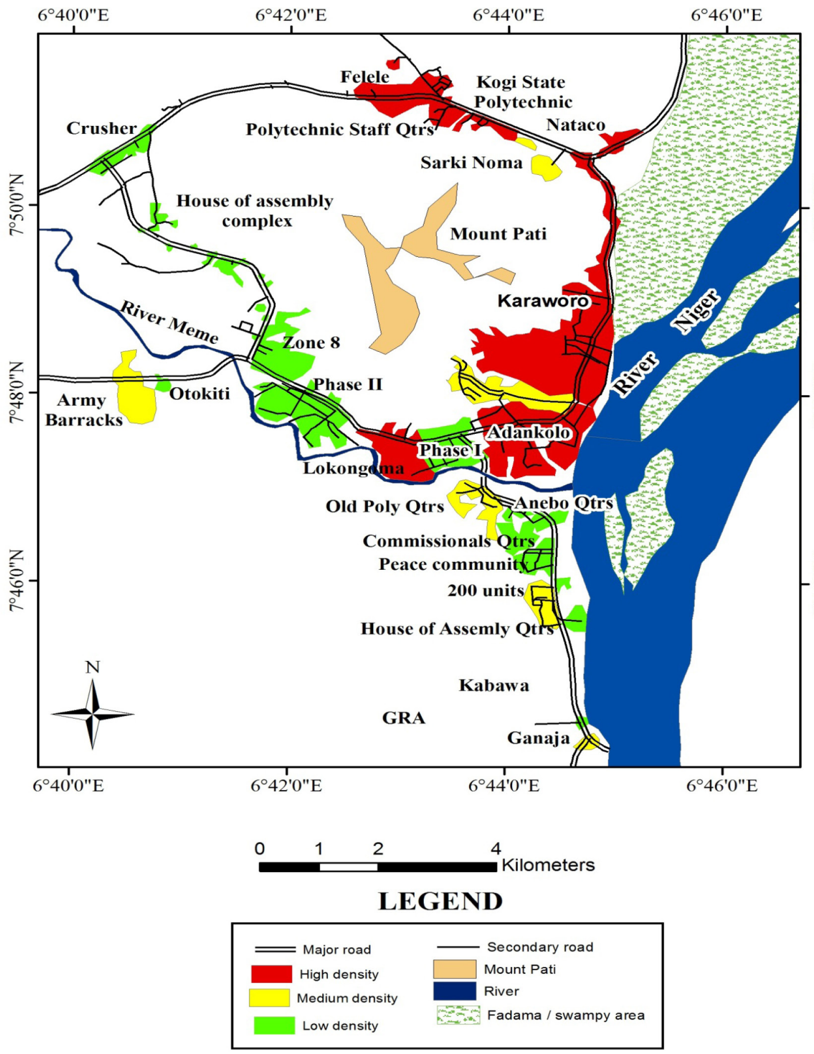

Figure 1. Map of the Study Area

3. Methodology

A primary data source was basically used for the present study. The study area was grouped into three residential densities based on land use characteristics and population densities. These three residential densities identified in Lokoja Metropolis are high, medium and low residential densities. The high density areas include the old residential areas such as Karaworo, Kabawa, Adankolo and Felele. Among the medium density areas are Old Poly Quarters, Gadumo, Zango, Phase One and Two Housing Estates, while the low density areas include Commissioners'' Quarters, Zone Eight, Two Hundred and Five Hundred Housing Estates. In each of the residential densities, an average of forty structured questionnaires was distributed to the head of households on how waste is being managed. A systematic random sampling technique was adopted on the principle of one in every ten buildings along selected major streets within the Metropolis. In each of the selected building, one household head was chosen for questionnaire administration. The data obtained include waste disposal methods by residents, distance of dumping sites to residential units and as well as residents' awareness of the risks involved in keeping solid waste for a long period of time in their neighborhoods. Descriptive statistics such as tables of percentages and analyses of variance was employed to analyze the results of the findings. Besides, principal component analysis was used to examine the factors affecting environmental health in the study area. These factors include, residential location, household size, educational background, distance to public waste collection site, awareness of risk involved in keeping waste in the residence for a long period of time, type of waste generated, among others.

4. Results of the Findings

4.1. Types of Waste Generated

Some of the urban centers in Nigeria are littered with solid waste in all nook and cranny which pollute our natural environment, and this consequently has a negative externality effect on human health. Table 1 reveals that agricultural waste and different types of polythene bags constituted the largest proportion of the solid waste generated in Lokoja Metropolis and this accounted for about 19.2% and 48.5% of agricultural residues and polythene bags respectively. A bulk of the agricultural waste (73.7%) emanates from the high density area of Lokoja Metropolis. The reason for this could be the local markets located at the high density area of city, where the majority of the agricultural products produce in the rural communities of the state and other adjoining states are brought for sale as a result of the large population size in the town. Also, the findings reveal that waste generated from paper of different kinds was ranked third (26.3%) as a type of the solid waste generated in the city. In the last three decades, urbanization trends in Nigerian cities have led to a high demand for the manufactured goods such as electronics, computer and many others. These manufactured goods are packed with cartons, leathers of different types and polythene bags which constitute in no small measure to waste generated in the city. Industrial waste is the lowest volume of waste generated in Lokoja and this accounts for only 3% of the waste generated. These include electronic waste and others.

Beside the solid waste generated in the city, excreta constitutes a significant proportion of the waste which are dumped in open spaces, uncompleted buildings and sometimes in drainages and along river channels. This constitutes serious environmental threat to urban residents in the city. As high as 66.7% of the excreta generated come principally from the high density areas of Lokoja, most especially at Kabawa, Adankolo and Karaworo where the early settlers reside.

Table 1. Waste Generated by Household Members Across Residential Density (in Percentage)

Residential Zone	Type of waste generated				
	Agricultural waste (Organic waste)	Industrial waste	Paper waste	Leather/ nylon bag/ carton	Excreta
High Density Area	73.7	0.0	19.2	39.6	66.7
Medium Density Area	26.3	66.7	38.5	41.7	0.0
Low Density Area	0.0	33.3	42.3	18.7	33.3
Total	100%	100%	100%	100%	100%

Source: Authors' Field Survey, 2014.

4.2. Waste Collection Points

Inadequate and non-existence of accredited waste collection points in the neighborhoods of many urban centers in Nigeria has resulted to indiscriminate dumping of solid waste in different parts of the city. This constitutes negative externality effects on human health. Table 2 shows that 55.6% of the respondents in the study area claim that there is no accredited waste collection points in their neighborhoods. Approximately 44.4% of the residents indicate that they have waste collection points close to their residences in Lokoja Metropolis.

Table 2. Accessibility to Dump Site around the Neighborhoods

Possession of waste collection points	Percentage
Yes	44.4
No	55.6
Total	100.0

Source: Authors' Field Survey, 2014

4.3. Waste Management Practices in Lokoja

Solid waste is not properly disposed in some of the ancient cities in Nigeria. Indiscriminate dumping of refuse in all nook and cranny of the urban centers has become the order of the day in Nigeria. Table 3 reveals that 64.6% of the residents in Lokoja burn their refuse in their neighborhood. This is considered to be an unhealthy way of waste disposal method as the smoke emanating from burning pollutes the air in the immediate environment. Further analysis reveals that 20.8% of residents in Lokoja indicate that they dispose their waste at the accredited road intersections where the public waste disposal vehicles come to collect the waste deposited. The uncoordinated way of dumping waste along the road sides affect the free movement of pedestrians as well as motorists in the city. Similarly, an approximately 16.8% of the sampled population in Lokoja Metropolis who live close to the trenches of streams and erosion channels dispose their waste in to water bodies for onward transmission to bigger water bodies like Meme River and River Niger. This practice makes it difficult for the people to make use of the water from these two rivers for domestic purposes without proper treatment.

Table 3. Waste Management Practices in Lokoja

Management Practices	Percentage (%)
Burning of Solid Waste	63.6
Dumping of Waste in Public Waste Bin (Along road intersections)	19.8
Dumping of Waste in Drainages/Water Channels)	16.6
Total	100.0

Source: Authors' Field work, 2014

4.4. Modal Considerations for Waste Disposal in Lokoja Metropolis

The geographical locations of accredited waste collection sites in Lokoja are along the major road intersections where they are conveyed by public waste disposal vehicles to the approved dumped site at the outskirts of the city. Table 4 reveals that an overwhelming (84.1%) proportion of urban residents in Lokoja claim that they use different types of polythene bags to convey their waste to the waste collection sites. Some of the residents in this category claim that they pack their refuse in the polythene bags for days until they are filled before taking them to the waste collection points. Another unpalatable method of waste disposal among some residents in Lokoja is the conveyance of solid waste with the aid of motorcycles to the accredited dump sites. These types of waste disposal techniques are unhygienic for any country striving to achieve sustainable environmental development by the year 2025.

Table 4. Means of Conveying Waste to Public Waste Bin

Methods	Percent
Transporting solid waste by nylon bags to public waste bin	84.1
Motorcycles	9.1
Personal vehicles	6.8
Total	100.0

Source: Authors' Field Survey, 2014.

4.5. Periods of Keeping Waste in the Residence

For a better hygiene of the residents in any community, a prompt disposal of the waste is the most important factor to be considered. However, in some of the urban centers of Nigeria, solid waste is kept for a couple of days before disposal to the appropriate waste dump sites. The non-availability of waste collection points in some of the neighborhoods, coupled with the inadequacy of waste disposal vehicles in Lokoja can be responsible for keeping the wastes for a long period of time in their residential areas. Table 5 reveals that 82.5% of the households interviewed in Lokoja indicate that they keep their waste for less than three days. A significant (13.4%) proportion of the respondents keep their waste between 3-6 days while 6.1% of the residents keep their solid waste generated in their premises for more than six days before disposing of them. This method of keeping waste for a long period of time in residential units constitutes great threat to the health of urban dwellers because waste deposition serves as breeding grounds for disease vectors.

Table 5. Period of Keeping Solid Waste in the Neighborhoods

Time of Keeping waste	Percentage
Less than 3 days	82.5
3-6 days	13.4
More than 6days	4.1
Total	100.0

Source: Authors' Field Survey, 2014

4.6. Health Challenges of Waste Management in Lokoja Metropolis

Different types of health challenges are experienced by inhabitants of Lokoja. Table 6 reveals that 54.5% of the residents indicate that they have experienced malaria infections within the last six months. This can be attributed to the fact that the blockage of drainage channels impedes the free flow of water thereby serving as breeding grounds for mosquitoes (malaria carrying agents) and other vector diseases which are harmful to human health. Further analysis reveals that 40.7% of the inhabitants of Lokoja Metropolis indicated that they had dysentery within the last six months, while 4.8% of the residents indicated that they had Cholera. These diseases are peculiar characteristics of unhygienic environment.

Table 6. Households Health Challenges within the Neighborhoods

Diseases	Percentages
Malaria	54.5
Dysentery	40.7
Cholera	4.8
Total	100.0

Source: Authors' Field Survey, 2014

4.7. The Results of Principal Component Analysis on the Environmental Impact of Waste Disposal Methods in Lokoja

The result of principal component analysis also confirmed that the nonchalant attitude of the urban residents toward prompt solid waste disposal as well as a number of household sizes constitutes about 21.93% from a total 84.89% of the variance of factors affecting environmental health of the inhabitants of the city. Table 7 indicates that the type of residential unit occupied by the residents and the type of waste generated accounted for approximately 17.05% of the factors threatening human health in Lokoja. Also, Table 8 shows that the waste disposal methods (0.579) is the variable loaded on the factor 3 and accounts for about 13.30% of the variance of the factors threatening human health in the city. The level of awareness of the risk involved in keeping waste in the residence for long period of time accounted for 10.93% of the variance of the factors militating against human health in the city.

Table 7. Result of the Variance Explained byEnvironmental Health Challenges Emanating from Solid Waste Disposal
Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	%Variance	Cumulative %	Total	% of variance	Cumulative %
1	3.728	21.931	21.931	3.728	21.931	21.931
2	2.899	17.053	38.984	2.899	17.053	38.984
3	2.260	13.295	52.279	2.260	13.295	52.279
4	1.858	10.295	63.208	1.858	10.929	63.208
5	1.451	8.535	71.743	1.451	8.535	71.743
6	1.217	7.160	78.902	1.217	7.160	78.902
7	1.018	5.991	84.893	1.018	5.991	84.893
8	.735	4.322	89.215			
9	.521	3.064	92.279			
10	.482	2.836	95.115			
11	.298	1.755	96.870			
12	.227	1.335	98.205			
13	.141	.830	99.035			
14	.093	.546	99.581			
15	.054	.316	99.987			
16	.014	.083	99.980			
17	.003	.020	100.000			

Extracted Method: Principal Component Analysis - Source: Authors' Field Work, 2014

Table 8. Result of Component Matrix on Environmental Health Challenges Emanating from Solid Waste Disposal
Component Matrix [a]

Parameter	Component						
	1	2	3	4	5	6	7
Residential Zone	-.630	.528	-.092	.380	.265	-.179	-.020
Household Size	.492	.117	.018	-.208	-.507	-.453	-.190
Educational background of respondents	-.661	.156	-.079	-.408	-.053	.395	-.341
Types of residential unit occupied	.146	.783	.432	.151	-.129	-.018	.138
Do you have drainage channels in your house?	.478	-.330	-.567	.317	.298	-.167	.081
What is the average distance of your building from the next house?	-.231	.363	-.640	-.224	-.180	-.105	.432
Frequency of clearing of drainage channel Specify the waste receptacle type	.716	.195	-.360	-.337	.108	.140	.284
Do you have waste receptacle in your house?	-.604	.459	.148	.333	-.357	-.061	-.019
How often do you get rid of the waste from your House?	.439	.268	.187	-.021	.667	-.015	-.205
Period of keeping waste generated in your house before disposing it to the dumping site	-.046	.105	.579	-.533	.421	-.271	.107
Do you have dump site around your neighborhood?	.507	.509	.558	-.095	-.068	.108	.257
Health challenges of the residents within the last six months?	.346	.467	-.357	.226	.130	.490	-.295
Awareness of the risk involved in keeping waste in residential units for long period of time too long in your residence?	-.550	-.100	-.054	-.534	.081	.388	.350
If the dump site is more than 100 meter to your residence, how do you	-.108	-.518	.186	.464	.005	.049	.427
convey the solid waste generated to the dump site?	-.528	.463	-.164	.263	.395	-.170	.179
How do you dispose the solid waste from your neighborhood?	.150	-.343	.517	.414	-.051	.448	.121
State the types of waste generated by members of your household	.534	.557	-.200	.142	-.186	.231	.119

Extracted Method: Principal Component Analysis. - 7 components extracted

5. Conclusions and Recommendation

Disposal of solid waste has constituted a serious environmental threat to human existence in urban centers in the developing countries of the world. But this is more pronounced in some of the urban centers in Nigeria due to the high rate of urbanization trends within the last 25 years. It is on this background that the present study was designed to assess the environmental impact of solid waste disposal methods on the inhabitants of Lokoja so that appropriate modern methods of solid waste techniques could be recommended for the city and other urban centers in Nigeria at large. The findings reveal that majority of Lokoja residents burn the waste generated in their households which constitutes serious environmental risk to human health as the smoke emanating from the burnings pollute the natural environment. Similarly, nonchalant attitudes toward prompt disposal of the solid waste also accounted for the significant proportion of the variance of the factors affecting environmental health in the city.

The present study recommends that the waste recovery, re-use and recycling techniques should be embraced as this method is practiced in some of the advanced countries of the world. The study concludes that more research needs to be carried out on waste management techniques in some of the urban centres in Nigeria and other African countries at large.

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Water Budget Assessment for a Typical Watershed in the Karak Plateau, Jordan

Ibrahim M. Oroud*

Mu'tah University , Karak, Jordan

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Abstract

Adequate assessment of water resources in arid and semiarid watersheds is essential for several purposes, such as the evaluation of biotic potentials for agricultural and grazing practices and for designing water dams. The water balance components of the watersheds in these environments are poorly understood due to the lack or the total absence of hydro-meteorological measurements. Simulation models would more likely fill this gap and can be applied to gauge these resources. The present investigation implements a physically based model with relatively fine spatial and temporal resolutions to examine the water budget components in the Numera catchment, a typical medium sized watershed draining the southwestern parts of the Karak Plateau.

The model was able to reproduce the energy balance components adequately, and the results compared favorably well with the observed data. Simulated results of the various water budget components are comparable to those obtained in similar environments. The average annual blue water fluxes (surface runoff and deep recharge) in this catchment is calculated to be ~ 3.3 million m^3 during the simulation period, 1996/1997 through 2001/2006. Blue water fluxes are generated primarily in the highlands of the watershed where relatively ample precipitation occurs. Steep terrains with limited vegetation cover experience significant runoff, implying the production of large quantities of sediments. The substantial sediment yield from these landscapes has serious adverse consequences on water quality and the life spans of dams constructed over these watersheds. It is imperative, therefore, that the sediment control via watershed management e.g., terracing, grazing control, preservation of native plants) be specified as a mandatory measure before constructing any dams over these watersheds.

Keywords: Karak Plateau, semiarid environments, sediment control, water balance partitioning, spatial modeling.

1. Introduction

Being located mainly in an arid environment, Jordan suffers from chronic water problems that exacerbats further with time. The average volume of precipitation falling on the country as a whole is around 8 billion m^{3}annually, with a value ranging from a minimum of less than 5 billion m^3 in very dry years to a maximum of 17 billion m^3 in wet years (Ministry of Water and Irrigation, 2012). The water shortage in the country will deteriorate further in the near future due to the steady growth of population resulting from natural growth and forced immigration, and also due to climatic changes towards warmer and drier conditions (e.g., Zhang et al., 2005; Oroud, 2008; Menzel et al., 2009; Sowers et al., 2011). A large fraction of the renewable water resources in Jordan is generated in the mountainous areas due to the relatively good amount of precipitation falling there compared to the rest of the country. The mountainous region where the average annual precipitation exceeds 200 mm represents ~ 10% of the total area of the country. Detailed calculations by the author of isohyets using GIS indicate that this region receives on average ~32% of the total precipitation falling on the country as a whole, and generates more than 65% of the renewable water resources.

Most watersheds in Jordan suffer from a lack of any type of meteorological and/or hydrological measurements, and where such measurements exist they are usually of poor quality, and in most cases the flood records do not reflect precipitation events. For instance, the Karak Plateau recorded, on the 22/23 of March, 1991, a significant amount of precipitation randing from 160 mm in Rabba to 245 mm in the city of Karak, causing a massive flooding in all wadies draining the plateau, yet the average daily discharges of Wadi Mujib, Wadi Karak, Wadi Numera and Wadi Ibin Hammad, for the 23, 24, 25 of March, 1991, as provided by archives of the Ministry of Water and Irrigation, 2001, were 0.038, 0.274, 0.061, and 0.19 m^3/second, respectivel!. Unfortunately, such erroneous "records" are implemented in calibrating models and in planning dams, culverts, and bridges. The deficiency and/or very poor quality of such measurements, in most catchments along with the poor knowledge of the fluvial processes controlling rainfall-runoff dynamics, have led to serious miscalculations of the capacity of dams, bridges and culverts constructed over many catchments in this region. For example, the maximum storage capacity design of both the Wadi Walla and the Wadi Mujib Dams were seriously underestimated, being 8 and 36 million m^3, respectively. During their operational period, which started around 10 years ago, the volume of overflow during flooding events exceeded the volume of water stored behind them. To reduce the flood water lost from the Wala Dam, the MWI implemented a plan in 2014 to increase the dam's

* Corresponding author. e-mail: ibrahimoroud@yahoo.com

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capacity to 25 M m^3. In addition to its inadequate design, the Mujib Dam suffers from very serious sedimentation problem ; a study conducted in 2008 by Margane et al. (2008), after only five years of operation, showed that the sediment thickness in some parts of the dam exceeded 14 meters. Such results point to a serious misunderstanding of fluvial processes controlling runoff and sediment production in this environment.

The chronic water shortage in the country along with the increased demands on water resources for the various sectors and to maximize water harvesting, the Jordanian governmentnis planning to construct dams on the main watersheds draining the Karak Plateau. There are four major catchments draining this plateau, Wadi Mujib, Wadi Ibin Hamad, Wadi Karak, and Wadi Numeira. These watersheds suffer from a lack of adequate hydro-meteorological measurement . This being the case, there is an urgent need to adequately assess the water resources potentials there. This assessment is vital for the proper designing and the management of the proposed new dams on these watersheds.

The present paper examines the water budget components of the Numera catchment, which represents typical watershed draining parts of the Karak Plateau. A transient hydrological model with a spatial resolution of one km^2 was run for six continuous years using daily meteorological data collected at nearby meteorological stations operated by the Ministry of Agriculture and the Department of Meteorology, Jordan. Results of this study are operationally important, as they provide the decision makers with realistic estimates of surface runoff and underground recharge, and thus decisions concerning the construction of dams in this watershed or on similar nearby watersheds can be based on scientific grounds rather than on "educated guessing" or poor data records.

2. Study Area

The Numera watershed, located around 15 km south of Karak city, covers an area of 100 km^2 and located between latitudes 31.00 and 31.08 degrees North and longitude 35 31 and 35 42 degrees East (Figure 1). The basin may be divided, from a climatological/ topographic perspective, into three zone : The highland (where Mediterranean soil and climate prevail), the middle basin (which represents a transitional zone between the highland and the Jordan Rift), and, finally, the lowland (which is simply part of the Jordan Rift).

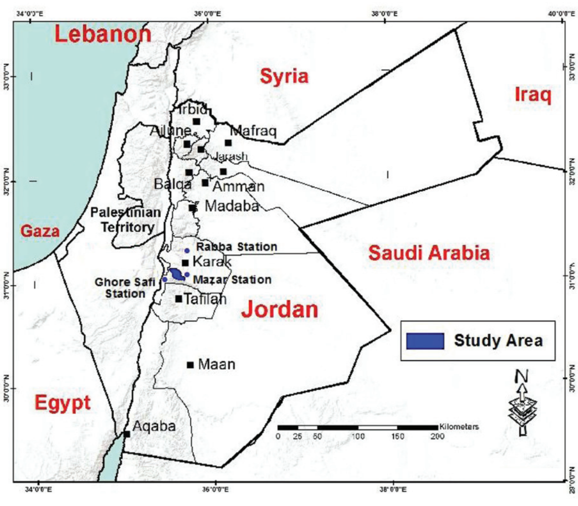

Figure 1. Location of study area.

Figure 2, a digital elevation model obtained from data collected by Aster Satellite with a spatial resolution of 15 m, shows the physiographic setting of the watershed. The basin spans a great relief differentiation, with the elevation ranging from ~ 1300 m above sea level to less than 300 m below sea level. Figure 3 shows the percentage of the area of the basin occupying a given contour interval. The area situated above 600 m represents around 68% of basin, whereas the corresponding value of the areas below 600 m contour line is around 32% only. This indicates that the major portion of the basin is situated in the highlands, and has good water resources potential.

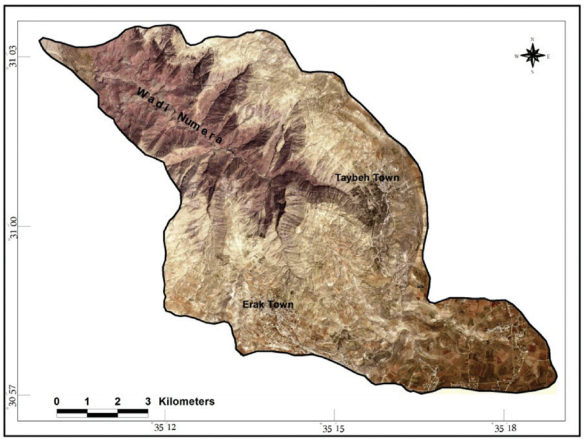

Figure 2. Physiographic and land use patterns of the catchment area.

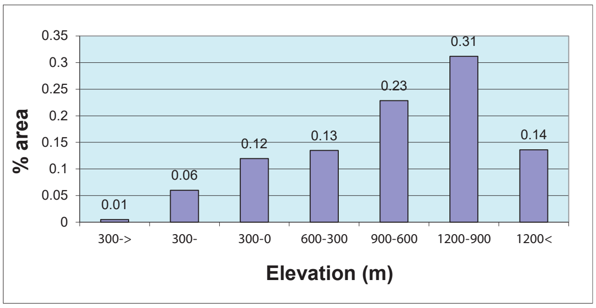

Figure 3. Percentage of area enclosed within 300 m contour intervals.

The highland is composed of Mediterranean red soil which has a good water holding capacity, making it suitable for the cultivation of grains, legumes, summer vegetables and some olive and fruit trees. The middle part of the basin has a yellow soil which reflects the dry conditions prevailing there. Some irrigated agriculture prevails in this part of the basin. The lower reaches of the basin are composed mainly of sandstone with very little soil cover. The basin encompasses a wide range of the climate and vegetation assemblages. The average annual precipitation varies from ~ 310 mm in the highlands where the Mediterranean climate prevails to less than 100 mm in the lower parts near the Dead Sea shoreline. The number of the rainy days with a daily precipitation exceeding 1 mm ranges from ~31 days in the highlands to ~14 days near the Jordan Rift. Substantial inter-annual precipitation variation occurs in this watershed, with a coefficient of variation exceeding 33%. The annual precipitation during the period 1972 through 2014, in a meteorological station situated at the watershed divide in the highlands, varied from a maximum of 560 mm in a very wet year to less than 120 mm in the driest year. This strong annual precipitation variation is an endemic character of the plateau with adverse consequences on agricultural practices there. Average January daily temperature within the basin ranges from values close to 5 °Celsius in the highlands to more than ~14 °Celsius near the Dead Sea (Oroud, 2011). Subfreezing temperatures occur in the highlands during the cold part of the year, but their occurrence is seldom near the Dead Sea (Oroud, 2007). Being located in a subtropical zone with dominant subsidence, the basin receives an ample amount of solar radiation exceesing 7000 MJ m^{-2} $year^{-1}$. The large amount of the annual solar radiation reveals the substantial radiative power available for evapotranspiration processes.

On average, the upper parts of the basin enjoy a Mediterranean-like climate whereas the lower parts experience hyper-arid conditions. The dryness index, which represents the ratio of potential evaporation to average annual precipitation ($Ø=P_E/P$), varies from 3.5 in the highlands to ~25 in the lower parts of the basin. From an agricultural perspective, rain-fed agriculture could be practiced in areas with a dryness index of less than 5, and controlled grazing in areas with a dryness index between 5 and 10. Areas with a dryness index exceeding 10 are highly fragile to anthropogenic activities, e.g., grazing, with significant adverse consequences on soil erosion and sediment production.

The diversity of terrain, geology, soils, and microclimates had led to intriguing plant assemblages across the basin. Natural vegetation is composed of perennial bushes covering the slopes of the highlands. Low laying bushes are scattered in areas receiving more than 200 mm of annual precipitation. These plant communities are more prevalent on north-facing slopes, where microclimates and soil moisture regimes are more favorable for plant growth. Only drought resistant/ evasive xerophytes can survive the very harsh environmental conditions in the lower parts of the basin (Oroud, 2010); patchy plant communities scatter along the washes of wadies and near the shallow ground water where enough moisture penetrates beneath the wadi beds.

The basin has five small settlements located in the upper parts of the basin, with a population close to 7000 inhabitants, and these settlements cover ~ 2% of the basin. Dry-fed agriculture prevails in the upper parts and represents around 33% of the basin. Rangeland with a relatively good native vegetation cover comprises around 15% of the basin. Denuded areas and rocky terrains represent ~ 50% of the basin. There are a few small springs emerging in the middle of the basin, allowing for the cultivation of irrigated crops such as grapes, olives and orchards over limited areas.

3. Method of Investigation

The present model integrates the daily surface energy and the soil water balances to simulate precipitation partitioning into evapotranspiration, surface runoff and deep recharge. The water budget of a soil column, where precipitation is the only moisture source, may be expressed in the following form (e.g., Gleick, 1987; McMahon et al., 2013):

$$\frac{\delta S}{\delta t} = P - E_T - R_O - D_p \qquad (1)$$

where δS/δt is soil moisture change with time, P, E_T, R_O, and D_P, are precipitation, actual evapotranspiration, surface runoff, and deep percolation, respectively, all terms are expressed in L/T. In arid and semiarid environments, actual evapotranspiration is the largest component on the right hand side of En. 1, and as such small errors in this term lead to large absolute errors in the estimates of runoff and deep recharge (e.g., McMahon et al., 2013), and its accurate formulation is quite important. Actual evapotranspiration is either energy-limited or moisture-limited (Alley, 1984; McMahon et al., 2013) and is functionally controlled by available energy, radiative and advective, and soil moisture regime (e.g., Oroud, 2011):

$$E_T = f(P_E, S_m) \qquad (2)$$

where E_T is actual evapotranspiration, P_E is potential evaporation which is a thermal index, and S_m is soil moisture availability as influenced by the hydraulic properties of the soil. Potential evapotranspiration is largely controlled by surface net radiation (e.g., Oroud, 2011; McMahon et al., 2013). The energy budget at the surface-atmosphere boundary may be expressed in the following form (e.g., Oroud, 1999; Oroud, 2011):

$$\mathrm{Rn} = \mathrm{S}(1 - \alpha_s) + L_{\downarrow} - L\uparrow \qquad (3)$$

where Rn, S, α_s, , are net radiation, global radiation, surface albedo, incoming atmospheric and emitted surface long wave radiation (Wm^{-2}), respectively. Eq. 3 represents the radiative component of the atmospheric forcings determining potential evapotranspiration (McMahon et al., 2013). The various terms which influence net radiation are solar radiation absorption, incoming long wave atmospheric radiation and emitted surface radiation. These terms were calculated from observed and interpolated meteorological elements obtained from the nearby meteorological stations.

Solar radiation is estimated from sunshine hours and extraterrestrial radiation at the top of the atmosphere. Extraterrestrial solar radiation (s_{ext}) over a flat surface is determined by solar declination and geographic latitude (Iqbal, 1983):

$$S_{ext} = \int_{sr}^{ss} \mathrm{Go}\, dt \qquad (4)$$

where Go is the solar radiation reaching the top of atmosphere at a given latitude (see Iqbal, 1983), sr and ss are sunrise and sunset, respectively. Global solar radiation is calculated for each resolution cell using the following form (Iqbal, 1983):

$$S = S_{ext}\,(\mu_o + \gamma \frac{n}{N}) \qquad (5)$$

where S is daily global solar radiation, μ_o is the fraction of extraterrestrial solar radiation reaching the surface during overcast conditions, g is the slope of the regression line linking surface solar radiation to sunshine hours , n and N are actual sunshine hours and theoretical daylight length, respectively. The values of μ_o and g are widely reported to be 0.25 and 0.5, respectively (e.g., Iqbal, 1983; Allen et al., 1998). Solar radiation correction for the elevation difference in the catchment was introduced after Allen et al. (1998).

Atmospheric radiation is calculated using the formulation presented by Brutsaert (1982):

$$L\downarrow = \varepsilon_a \sigma T_a^4 \qquad (6)$$

where T_a is near surface air temperature (K), ε_a is atmospheric emissivity which is determined primarily by water vapor concentration in the lower troposphere (e.g., Oroud and Nasserallah, 1998). Atmospheric emissivity ranges from values close to 0.72 in a relatively dry cold atmosphere similar to clear cold winter nights in Jordan to more than 0.95 during overcast conditions with low level clouds. Emitted surface radiation is determined primarily by surface temperature and the level of surface moisture; surface emissivity ranges from ~0.94 for dry soils to 0.97 for wet soils. Surface albedo and surface emissivity were assumed to be 0.23, and 0.96, respectively.

The soil fabric in each resolution cell is assumed to be comprised of two compartments, a relatively thin layer at the top and a deep layer. The top layer is assumed to hold 0.2 of water stored in the entire soil profile, and this assumption is consistent with the US Geological Survey Curve Number assumptions (e.g., Solomon and Cordery, 1984; Dingman, 1992; Nishat et al., 2007; Moroizumi et al., 2009). This depth also provides an adequate assessment of actual evapotranspiration from the soil profile (e.g., Romano and Giudici, 2009). Actual evapotranspiration from the soil is calculated using the following form (e.g., Liu and Smedt, 2004):

$$E_T = \begin{bmatrix} P_E, P \geq P_E \\ (P - P_E)\left(\frac{(m_1 - \lambda)}{(F_{c1} - \lambda)}\right)^3 + (P_E - \beta)\frac{(m_2 - w_{p2})}{(f_{c1} - w_{p1} + f_{c2} - w_{p2})}, P < P_E \end{bmatrix} \quad (7)$$

where P_E is potential evapotranspiration, m_1 and m_2 are upper and lower layers moisture, λ is air dry soil moisture, and β is evapotranspiration from the first layer, F_{c1} and F_{c2} are field capacity of upper and lower soil layers, w_{p1} and w_{p2} are wilting points for layers 1 and 2. Potential evapotranspiration is calculated using the Penman method as modified by Allen et al. (1998); this formulation accounts for the radiative (net radiation) and advective (wind speed, surface roughness, and vapor pressure deficit) components. In this formulation, evapotranspiration takes place from the top layer only when this layer is at field capacity, but abstraction from the lower layer occurs when atmospheric demands are not met from the first layer. In Eq. 7, evaporation and transpiration proceed from the top layer, whereas only transpiration occurs from the second deeper layer. The first layer has limited plant available moisture, and therefore the water loss from this layer is determined primarily by soil evaporation. It is well-known that the soil evaporation decreases non-linearly as soil water content decreases (e.g., Ritchie, 1972; Alley, 1984; Liu and Smedt, 2004; McMahon et al., 2013). To make the parameterization consistent with plant phenology, it is assumed that transpiration for areas situated above 700 m occurs during the period, end of January through end of June. This assumption is consistent with field crops grown in this area which usually start to emerge and develop after the end of January in the highlands in the eastern Mediterranean due to the cold temperatures there (e.g., Oroud, 2012).

Surface runoff and deep recharge are calculated using a bucket method such that when the first layer reaches its field capacity, excess water there is drained to the deeper layer. Excess water in the deeper layer beyond field capacity is assumed to be lost as deep recharge. This occurs when the two soil layers reach their field capacities. Runoff occurs when daily precipitation exceeds soil saturation of the top layer and a retention parameter (e.g., Nishat et al., 2007; Moroizumi et al., 2009):

$$\begin{aligned} &\mathrm{Ro} > 0 : \mathrm{P} > (\theta_{s1} + \psi) \\ &\mathrm{Ro} = 0, \text{otherwise} \end{aligned} \quad (8)$$

where Ro is surface runoff, θ_{si} is soil layer saturation, ψ is a retention parameter which accounts for rainwater trapped in surface irregularities and micro reliefs.

It is assumed in this formulation that snow occurs when the average daily air temperature of a resolution cell is 3 °C or less (e.g., Dingman, 1992). The mass of melted snow is a complex function of daily solar radiation, conduction from the underlying ground, sensible heat flux exchange due to turbulent mixing, atmospheric humidity, and downward long wave radiation from cloud cover, particularly low clouds (e.g., Dingman, 1992; Oroud and Nasserallah, 1998). Due to the complexity of the snow melting processes, the widely used degree day method (e.g., Solomon and Cordery, 1984; Liu and De Smedt, 2004) is employed in the present paper. This parameterization is expected to be confined to the highland, as precipitation in the form of snow does not usually occur below 700 m in this basin.

3. Model Input

The various physical properties such as hydraulic properties of soil, grid slope, land cover/ use, and climate gradient were extracted from field surveys, topographic maps, remote sensing images, and GIS tools. Soil characterizations – in terms of soil thickness, porosity, field capacity, wilting point, and air dry properties – were deduced from field surveys, soil maps, and physiognomy of each resolution cell. Average soil properties of each cell were tabulated using soil and topographic maps. Soil porosity ranges from 0.46 for clay like soils to around 0.43 for sandy like soils (e.g., Nimo, 1984). Field capacity for the clayey soils in the mountainous areas, where relatively deep Mediterranean soils dominate, is around 0.36 and wilting point is ~ 0.24; corresponding values for sand like soil are 0.14 and 0.06, respectively. These values are consistent with values reported for this type of soil in this environment (Dingman, 1992). The influence of slope on the soil hydraulic properties was taken into account when calculating the effective holding capacity such that effective holding capacity decreases as slope increases beyond a given threshold level.

The catchment does not have any hydrological or meteorological stations, and thus meteorological data observed in the nearby locations were employed to generate the needed atmospheric data to calculate the energy and water balance components of each resolution grid. Precipitation is obtained from daily measurements observed in the southern Mazar station, located near the watershed divide in the highlands. The upper portions of this watershed experiences climatic conditions similar to those prevailing over the station. Precipitation series observed in this station were cross correlated with corresponding values observed at Rabba station, a first class meteorological station located about 20 km north of the catchment area and operated by the Department of Meteorology, Jordan. A good correlation was obtained and missing data at Mazar station were filled using the regression method. Precipitation falling on each grid could be obtained using a variety of methods, such as the Inverse Distance, the Krigging or the Contour Line (e.g., Dingman, 1992). Due to the steep elevation gradient, the Contour Line would be the most suitable interpolation method because of the steep precipitation gradient across the basin. Precipitation data for a station located at the highland and another one situated near the southern end of the Dead Sea were employed to extrapolate precipitation at each resolution grid. As an independent check, the assemblages of natural vegetation and land use patterns were utilized as a proxy indicator of the precipitation gradient.

Daily meteorological data gathered at Rabba meteorological station were implemented to extrapolate solar radiation, air temperature, atmospheric water vapor pressure, wind speed, and cloud cover after taking into account average elevation of each cell. Air temperature gradient between the mountainous station located at 920 m and the one near the southern edge of the Dead Sea (-350 m) was found to range from 0.006 °C/m in January to about 0.007 °C/m in July. This temperature gradient is commensurate with the widely documented environmental lapse rate of 0.0065 °C/m observed in the lower troposphere. Ambient vapor pressure depends strongly on air temperature (e.g., Allen et al., 1998). Figure 4 shows the linkage between the average monthly air temperature and the average monthly actual vapor pressure for two stations situated near the drainage basin, one in the mountains and the other near the Dead Sea. Given this strong linkage, the actual vapor pressure for each cell is determined using the following expression (Oroud, 1998):

$$e_a(j,i) = e_a + \frac{\partial e}{\partial T}\frac{\partial T}{\partial z}\delta z \qquad (9)$$

where $e_a(j,i)$ is actual vapor pressure of cell j,i, e_a is the observed actual vapor pressure at the meteorological station, and δz is elevation difference between the meteorological station and the intended cell. It is widely known that ambient water vapor pressure is closely linked to near surface air temperature.

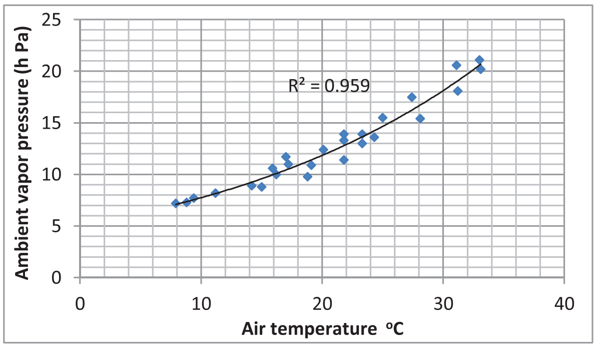

Figure 4. Linkage between average monthly air temperature and average monthly actual vapor pressure for two stations situated near the drainage basin.

5. Model Results

The simulated daily solar radiation in the highlands ranged from 10.2 MJ m^{-2} in December to 30.6 MJ m^{-2} in June, respectively. The corresponding simulated values for the lower parts of the basin near the Dead Sea were 10.6 and 28 MJ m^{-2} day^{-1} in December and June, respectively. Global solar radiation observed by the author in the mountainous area during December and June, 2010 were 9.8 and 29.9 MJ m^{-2} day, respectively. Figure 5.a shows a typical diurnal solar radiation regime in the mountainous areas near the watershed divide during June. Likewise, the long term observed daily solar radiation reaching the Dead Sea area in December and June were reported to be 10 and 27.5 MJ $m^{-2}.day^{-1}$, respectively (Hecht and Gertman, 2003). These results lend a strong support to the adequacy of the input values for the model. Figure 5.b shows the spatial distribution of simulated solar radiation reaching the watershed during December.

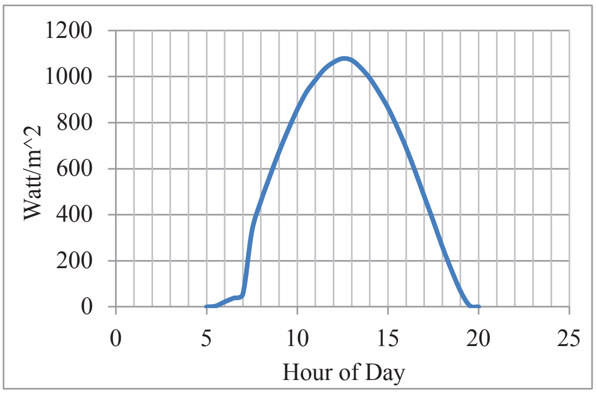

Figure 5.a. A typical diurnal solar radiation regime in the mountainous areas as observed by author during June. The slight dip in the early morning hour is due to the obstruction of sun by an obstacle.

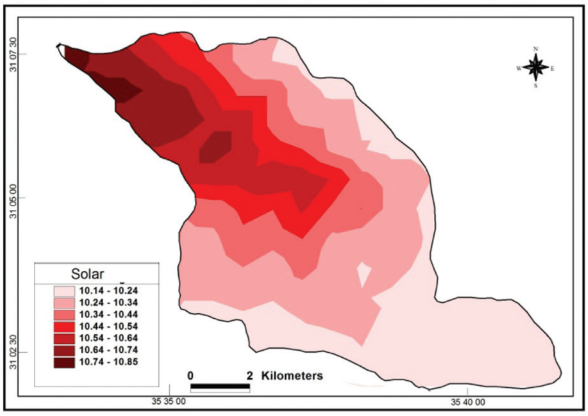

Figure 5.b. Simulated daily solar radiation during December (MJ m^{-2}. day^{-1}).

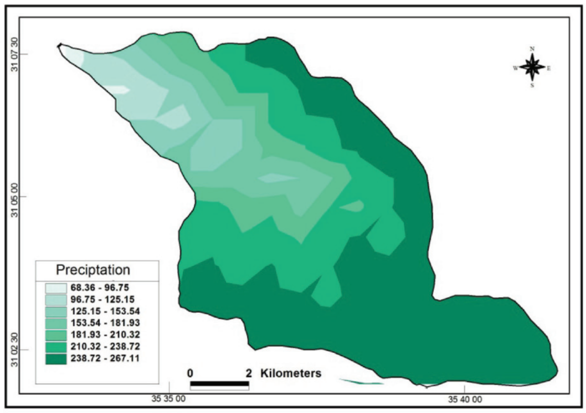

Figure 6. Spatial distribution of average annual precipitation across the basin.

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Annual precipitation is characterized by a steep gradient across the watershed, ranging from 270 mm in the highlands to about 70 mm in the lower portions during the simulation period (Figure 6).

During the six-year period, the average annual areal precipitation falling on the basin as a whole was around 26 million m^3. Annual potential 1750 mm in the lower reaches of the basin (Figure 7).

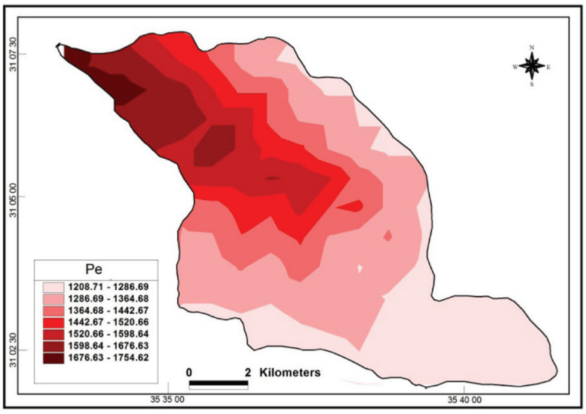

Figure 7. Potential evapotranspiration across the basin during December through end of March.

Of special importanc is the evaporative power of the contiguous atmosphere during the period of December through the end of March, as more than 80% of precipitation falls during this time. During this period, PE ranges from ~185 mm in the mountainous areas to ~330 mm in the lower reaches of the basin. Figure 8 shows the spatial distribution of average actual evapotranspiration (AE) during the cold part of the year, December through the end of March. During this time of year, AT ranges from 70 mm in the lower part of the basin to about 130 mm in the highlands. The ratio of AT to precipitation during the cold part of the year ranges from figures close to100% in the lower parts to about 65%-70% in the highlands. The meager amount of precipitation along with the significant evaporative power in the lower parts is responsible for the total loss of precipitation by direct evaporation.

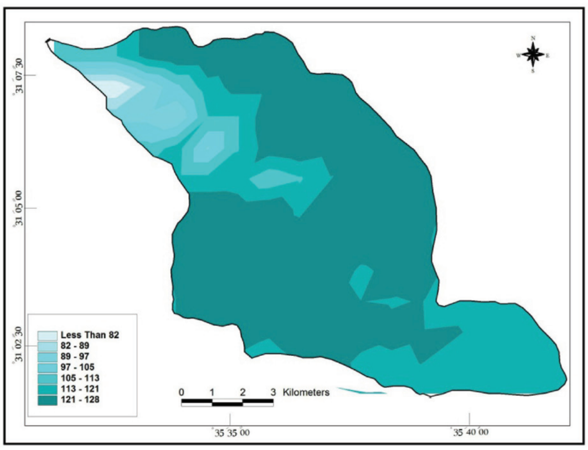

Figure 8. Actual evapotranspiration across the basin during December through end of March.

Runoff displays a substantial spatial heterogeneity across the basin, ranging from 55 mm over steep terrains to zero near the Dead Sea shoreline (Figure 9). A significant runoff occurs over steep slopes where the surface is devoid of vegetation and the soil is relatively thin. Runoff in semiarid areas has been reported to represent a significant fraction of annual precipitation, particularly for bare, low storage surfaces (e.g., Lal, 1991).

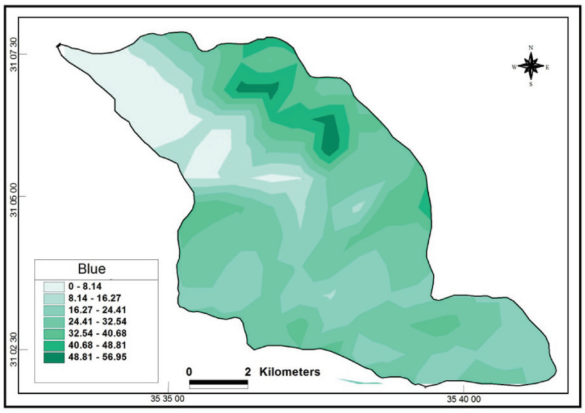

Figure 9. Spatial distribution of average runoff during six year the simulation period.

Relatively, little runoff is generated in the water divide as a result of the deep soils and the gentle slope there. Deep soils are characterized with a large water holding capacity which would explain the suitability of flat/ gentle sloping terrains in the watershed divide to agricultural practices, as large fractions of precipitation are stored in the deep soil profile and being subsequently consumed in plant transpiration (e.g., Al Qudah, 2001). The annual runoff generated in this catchment during the six-year simulation period was close to 2.0 million m^3. This catchment produces relatively little deep underground recharge which varies from less than 30 mm year^{-1} in limited areas in the highlands to almost zero in the lower reaches. Almost all the areas located below the 600 m contour line have a negligible contribution to underground recharge due to the scanty amount of precipitation and the high evaporative power of the contiguous atmosphere (Figure 10). Scanty precipitation events tend to wet a shallow soil layer which is subsequently lost to the contiguous atmosphere via direct evaporation, with little or absent contribution to runoff and underground recharge. The simulated underground recharge for the whole catchment, as delineated by its topographic water divide, is around 1.25 million m^3. The total blue water fluxes for the basin as a whole during the six-year period represented around 12.5% of areal precipitation. This ratio is consistent with those obtained in catchments situated in similar environments (e.g., Margane et al., 2005; Al Kuisi and El-Naqa, 2013; Schulz et al., 2013).

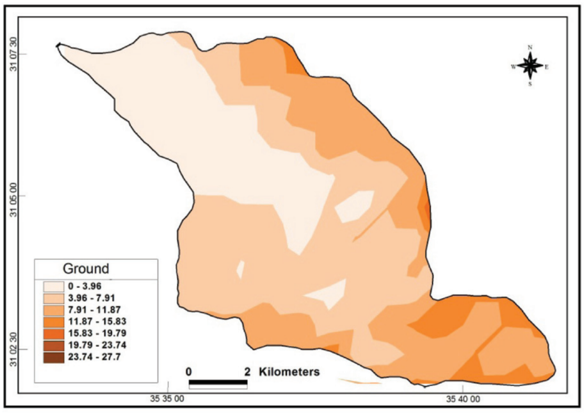

Figure 10. Spatial distribution of simulated underground recharge during the six year period.

6. Field measurements

The data compiled by the Ministry of Water and Irrigation (2012) for the period January, 1, 1990 through January, 31, 2010 indicate that the Numera Wadi, which drains the investigated catchment area, has an average water flow, including flooding, of ~ 1.53 Million m^3 per annum. Furthermore, a field campaign carried out by the author during Jul, 2013 indicated that the water emerging from the springs in the catchments was ~ 800 thousand m^3. Thus, total annual blue water fluxes from the catchment was around 2.3 million m^3 during the simulation period. The measured annual flow appears to be less than the simulated blue water yield by about one million m^3. Several reasons are responsible for this incongruity. In pars, measurements by the MWI are frequently faulty, as days with heavy precipitation as recorded in meteorological stations did not reflect any flooding event . Such records tend to underestimate actual blue water fluxes. In addition, measurements of spring discharges were carried out inrmid-summer, and thus measured flow is expected to be less than the sum over all months, as discharge from springs increases in winter and spring following rainy periods. Discharges from some springs were not measured and this has contributed to the discrepancy. Additionally, some water generated in the watershed is likely seeping directly to the Dead Sea, and this part is not accounted for. Despite this difference, simulated results are in line with previous studies carried out in similar catchments (e.g., Margane et al., 2005; Schultz et al., 2013).

7. Discussion and Conclusion

The Numera watershed represents a typical catchment in the Karak Plateau, and its water budget components are not expected to deviate appreciably from other catchments in the Plateau. Calculations show that the ratio of actual evapotranspiration for the catchment as a whole is around 87.5% of areal precipitation. Deep recharge occurs primarily in the highlands, and this is clearly confirmed by the abundance of the emerging springs in the areas located between 800- 900 m above mean sea level. It should be indicated that during the six-year simulation period, precipitation was less than the long term average by about 15% which means that blue water fluxes should have been larger than what is reported in the present paper. The elasticity of blue water fluxes to precipitation variations in this environment is quite large (e.g., Oroud, 2008; Yang and Yang, 2011). The results obtained in the present paper are congruent with previous studies conducted in catchments situated in different parts of Jordan. In a study to assess deep recharge and underground water susceptibility to pollution in the Lajune area, midway between Karak city and the desert highway near Qatraneh, Margane et al. (2005) indicated that the underground recharge varies from ~10 mm $year^{-1}$ in the drier realms to ~20 mm $year^{-1}$ in the less drier locations in the west and southwest of the catchment, which constitute ~ 4% to 9% of areal precipitation. Further, Schulz et al. (2013) indicated that the average annual underground recharge for the Amman-Zarqa underground basin is around 105 million m^3 (~ 21 mm $year^{-1}$) which represents around 9.5% of areal precipitation over the catchment. The ratio of the underground recharge increases in the more humid areas of the country; Hobler et al, (2001) estimated the underground recharge ratios for areas close to Ajlune and Salt cities, where the average annual precipitations in the range 600 - 550 mm are around 21.4% and 18.2% of annual precipitation, respectively. Blue water fluxes, both surface runoff and deep underground recharge, become insignificant, being less than 2%, in arid catchments in this region (e.g., Al Kuisi and El-Naqa, 2013); this is the case for the lower parts of the Numera basin, as shown in Figures 9 and 10, where the surface runoff and deep recharge are close to zero.

It has been shown that the deep soils in this catchment contribute less blue water than the thin soils or rocky terrains. As soil depth increases in this environment, a larger fraction of precipitation is stored in the soil fabric which is subsequently lost via transpiration (green water) rather than being partitioned via surface runoff and/or deep recharge. These results are consistent with field observations and simulations results carried out in similar environments (e.g., Bellot et al., 2001; Farmer et al., 2003; Ranjan et al., 2006; Seyfried and Wilcox, 2006), and ascertain the very delicate nature of runoff and deep recharge in these catchments (e.g., Alley, 1984).

An important outcome of this study is the pronounced disparity of surface runoff across the catchment with a significant runoff occurring over steep terrains in the highlands. Field surveys show that these slopes are highly dissected with numerous deep arroyos. These dissected landscapes and the wide spread of rills and gullies reveal the substantial erosional potentials over these slopes. Consequently, extra care must be exercised when constructing dams over these watersheds, as large volumes of sediments are produced, leading to severe shortening of life spans of these dams. An obvious example is the accumulation of large volumes of sediments in the Mujib Dam which gets a large portion of its water supply from the Karak Plateau. A joint Jordanian-German study conducted in 2008, only five years following the dam construction, indicated that the thickness of sediments in the Mujib Dam was in excess of 14 m in some parts of the dam (MWI, 2008). This result points out to serious misunderstandings of the fluvial processes controlling rainfall-runoff/sediment production in this environment. The implication of this finding is that erosion control over these catchments must be a mandatory step before any dam construction. Pioneering geomorphological studies (e.g., Langbein and Schum, 1958; Collins and Bras, 2008) have shown that the sediment yield reaches its maximum in areas receiving between 250- 300 mm of annual precipitation, decreasing sharply on both sides of this maximum, in the lower end owing to a deficiency of runoff and in the other to increased vegetation density. In fact, most important watersheds in Jordan are situated in this precipitation zone where the vegetation cover is quite sparse or even absent and soils are poorly managed. Thus, soil erosion management in these watersheds must be given an extra attention prior to constructing dams in this highly fragile environment.

The present model could be linked with an erosion model to delineate areas with serious erosional potentials that need to be managed adequately prior to dam construction. Results of the present study should be regarded as a first step in evaluating blue water fluxes from these catchments, and meteorological, hydrological, and geomorphological measurements need to be established in these watersheds to build a reliable data base to understand the linkage between rainfall - runoff/ sediment yield in this highly water stressed region.

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يرتبط الزنك الكلي بعلاقة ارتباط ايجابية معنوية مع المادة العضوية (r = 0.441**) ويتبين من الجدول(6) معادلة (1) بان26% من التغير بالزنك الكلي كان بسبب خصائص التربة المدروسة وكان التأثير معنوي بسبب المادة العضوية. وهذا يتوافق مع (Shivaram (1998 حيث وجد أن زيادة المحتوى من المادة العضوية يزيد من محتوى الزنك المدمص الى التربة.

يرتبط الزنك القابل للتبادل بعلاقة ارتباط سلبية معنوية مع الـ pH (r = -0.286*) ويتبين من الجدول (6) معادلة (2) بأنه ليس لخصائص الترب المدروسة أي تأثير معنوي على الزنك القابل للتبادل. كما نلاحظ بأنه يوجد علاقة ارتباط معنوية ايجابية بين الزنك المرتبط بالكربونات ومحتوى الترب من المادة العضوية (r = 0.625**) وتظهر معادلة الانحدار(3) بان 45% من التغير بمحتوى الترب من الزنك المرتبط بالكربونات كان بسبب الخصائص المدروسة وكان للمادة العضوية تأثير معنوي عل محتوى الترب من الزنك المرتبط بالكربونات. كما يرتبط الزنك المرتبط بأوكسيد الحديد والمنغنيز بعلاقة ارتباط ايجابية معنوية مع المادة العضوية (r = 0.579**) وهذا يتوافق مع (Wijebandara et al. 2011; Ashraf et al,. 2012) وتظهر معادلة الانحدار (4) في الجدول (6) بأن 37.9% من التغير بالزنك المرتبط بأوكسيد الحديد والمنغنيز كان بسبب الخصائص المدروسة وكان التأثير المعنوي بسبب المادة العضوية. يتبين من الجدول السابق (5) وجود علاقة ارتباط معنوية سلبية بين الزنك المرتبط بالمادة العضوية وكلاً من الـ pH (r = -0.355**) والكربونات الكلية (r = -0.350**) والكلس الفعال (r = -.451**) وهذا يتوافق مع (Ramzan et al, 2014) بينما كانت العلاقة ايجابية معنوية بين الزنك المرتبط بالمادة العضوية والمادة العضوية مما يدل على أن الحموض العضوية والمجموعات الوظيفية الأخرى تزودنا بمواقع للتبادل من أجل ادمصاص الزنك وهذا يتوافق مع (Prasad and Sakal 1988) ، حيث نلاحظ من معادلة الانحدار (5) بأن 54.4% من التغير بالزنك المرتبط بالمادة العضوية كان بسبب خصائص الترب المدروسة وكان التأثير المعنوي بسبب الكلس الفعال والمادة العضوية، وأما بالنسبة للشكل المتبقي فنلاحظ بأنه لا توجد علاقات ارتباط معنوية له مع خصائص التربة وبأن معادلة الانحدار غير معنوية معادلة (6) (R^2= 0.112)

الاستنتاجات:

1- تراوح تركيز الزنك الكلي بين56.7 الى 460.66 مغ/ كغ وبمتوسط 136.33 مغ/ كغ.
2- كان ترتيب أشكال الزنك بالاعتماد على المتوسط: المتبقي (72.14%) > المرتبط بأوكسيد الحديد والمنغنيز(% 22.78)> المرتبط بالمادة العضوية (2.40%) > المرتبط بالكربونات (% 2.24)> القابل للتبادل (0.43%).
3- كانت نسبة الأشكال المتاحة من الزنك عالية في ترب منطقة الاستقرار الثانية (35.35%) ومنخفضة في الرابعة (15.057%).
4- تظهر علاقات الارتباط بأن الزنك الكلي والمرتبط بالكربونات والمرتبط بأوكسيد الحديد والمنغنيز والمرتبط بالمادة العضوية يزداد مع زيادة المادة العضوية (r =0.441, 0.625, 0.573, 0.511).
5- ينخفض الزنك المرتبط بالمادة العضوية مع زيادة الـ pH (r =- 0.353) والكربونات الكلية (r = -0.350).
6- تظهر معادلات الانحدار وجود علاقات معنوية بين أشكال الزنك (الكلي، المرتبط بالكربونات، المرتبط بالمادة العضوية) والخصائص المدروسة في ترب من محافظة حمص.

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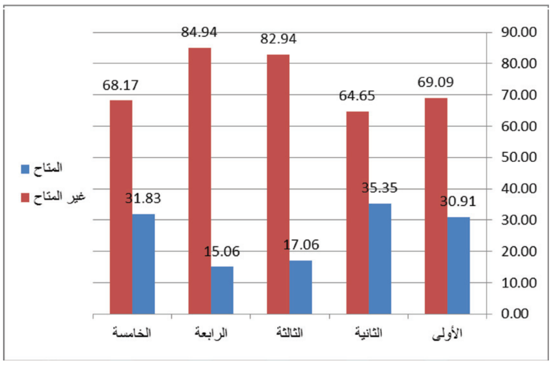
تراوح تركيز الشكل الثاني من الزنك (المرتبط بالكربونات) بين 37.35 mg/kg و 0.265 وبمتوسط 3.095 mg/kg وهذا من المحتمل أن يكون مؤشر على دور هذا الشكل بامداد التربة بالزنك، وعادة يتواجد هذا الشكل في الترب ذات الحموضة المرتفعة والعالية المحتوى من الكربونات Rajkumar (1994). ويعد الشكل المرتبط بأكسيد الحديد والمنغنيز الشكل الرئيسي من الأشكال غير المتبقية (residual fractions) حيث تراوح تركيزه بين 191.48 mg/ kg و 3.28 حيث يعتبر هذا الشكل الاكثر ثباتاً (Ma and Rao, 1997) وتدل هذه الأشكال الثابتة والمستقرة على أهميتها كونها مخزن رئيسي للزنك في التربة. كما يبين الجدول (5) محتوى الترب المدروسة من الزنك المرتبط بالمادة العضوية حيث تراوح بين 16.54 mg/kg و 0.35 وبمتوسط 3.28 mg/kg وينخفض هذا الجزء بعد سنوات من زراعة المحاصيل (Behera et al. 2008) وبهذه الحالة تعد المادة العضوية مهمة بصفتها مخزن مؤقت للزنك في التربة (Dvorak et al., 2003.)، ويعود السبب في ذلك الى تشكيل معقد مادة عضوية- زنك (Udom et al., 2004) ويرتفع محتوى الترب من هذا الشكل من الزنك مع ارتفاع محتواها من المادة العضوية وهذا ما توصل اليه العديد من الباحثين (Parasad et al., 1995, Randhawa and Singh, 1995, Hazara and Mandal, 1996).

تراوح تركيز الزنك المتبقي بين 289.54 mg/ kg، و 23.2 ويشكل هذا الشكل جزءاً كبيراً من اجمالي الزنك وتدل هذه النسبة الكبيرة من الزنك المتبقي الى ميلان الزنك ليصبح غير متوفر في التربة وذلك لأن هذه الاجزاء لن تكون متاحة الا في ظروف قاسية جداً (Ma and Rao, 1997) وتوافقت هذه الكميات الكبيرة مع العديد من الدراسات (Zauyah et al., 2004, Jaradat et al., 2006, Aydinalp, 2009, Kamali et al.,2010)

5.3. عامل الحركية للزنك في التربة (MF):

تكون معظم الأشكال الأولى في أي استخلاص تسلسلي متحركة ومتاحة حيوياً وبالتالي فإن قيم عامل الحركية تحدد الحركية والاتاحة البيولوجية للعناصر الصغرى لذلك فكلما ارتفعت قيمة (MF) زادت قدرة عنصر الزنك على الحركية والاتاحة للنبات (Kabala and Singh, 2001)، ويحسب هذا العامل من العلاقة التالية (Haung et al., 2010).:

MF = ((Exchangeable+ Carbonate bound+ Oxide bound +Organic bound)/ Total)* 100



شكل 3. تركيز الزنك المتاح وغير المتاح في التربة

يتبين من الشكل (3) قيم عامل الحركية وقد تراوح من 15.06 الى 35.35 ويعزى انخفاض قيم هذا العامل لعنصر الزنك الى مزيج من العوامل ومنها ربما انخفاض محتوى الترب من الزنك الكلي، وذوبانيته المنخفضة جداً من المعادن وادمصاصه القوي على سطح التربة أو بسبب الرشح مع المواد العضوية الذائبة (Rieuwerts et al., 2006) وتوافقت قيمة المعامل المنخفضة مع دراسات عديدة(McDonald et al., 2001, Obrador et al., 2007, Karak et al., 2006, Agbenin, 2003, Furlani et al., 2005, Cakmak et al., 1999, Maftoun and Karimian, 1989).

5.4. العلاقة بين أشكال الزنك والخصائص الفيزيو - كيميائية للتربة:

يتفاوت توزع الزنك على أشكاله كيميائية بسبب التغير في الخصائص الفيزيو- كيميائية للتربة (Adhikari and Rattan, 2007).، كما يعتمد النمو الجيد للنبات على توفر المغذيات المتاحة التي تضبط بخصائص التربة مثل النسيج ودرجة الحموضة والكربونات والمادة العضوية وسعة التبادل الكاتيوني (Bell and Dell, 2008, Wijebandara et al., 2011). ويبين الجدولين التاليين علاقات الارتباط بين الاشكال الكيميائية المختلفة للزنك وخصائص الترب، ومعادلات الانحدار المتعدد لتأثير الخصائص المدروسة على أشكال الزنك الكيميائية.

جدول 6. علاقات الارتباط بين الاشكال الكيميائية المختلفة للزنك وخصائص الترب المدروسة

Residual	Organic bound	Oxide bound	Carbonate bound	Exchangeable	Total	
-0.087	-0.355**	-0.067	-0.061	-.286*	-0.11	pH
-0.025	-0.062	0.036	0.076	-0.137	0.006	EC
-0.216	-0.350**	-0.093	-0.142	-0.096	-0.205	$CaCO_3$
-0.101	-.451**	-0.153	-0.167	-0.086	-0.175	ACTIVE LIME
0.176	0.228	0.094	0.187	-0.026	0.179	CEC
0.104	0.511**	0.579**	0.625**	0.177	0.441**	TOM
-0.108	-0.219	-0.228	-0.192	-0.11	-0.21	CLAY

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

جدول 7. معادلات الانحدار المتعدد لتأثير الخصائص المدروسة على أشكال الزنك الكيميائية

R^2	معادلة الانحدار	
0.260*	الشكل الكلي للزنك Y = 157.974 – 5.346 (pH) - 0.023 (EC) - 0.271 ($CaCO_3$) - 0.579 (LIME) + 0.783 (CEC) + 21.364 (OM)- 0.788 (Clay)	1
0.186	الشكل القابل للتبادل Y = 3.463 - 0.354 (pH) - 0.001 (EC) - 0.006 ($CaCO_3$) + 0.029 (LIME) - 0.012 (CEC) + 0.093(OM) - 0.002 (Clay)	2
0.453*	الشكل المرتبط بالكربونات + 0.346 (pH) - 0.001 (EC) + 0.129 ($CaCO_3$) - 0.523 (LIME) + 0.147 (CEC) + 2.579 (OM) +0.010 (Clay) Y = -7.810	3
0.379*	الشكل المرتبط بأوكسيد الحديد والمنغنيز 3.550 (pH) -0.015 (EC) +0.770 ($CaCO_3$) - 3.770 (LIME) + 0.495 (CEC) + 15.054 (OM) -0.082 (Clay) Y = -25.117+	4
0.544*	الشكل المرتبط بالمادة العضوية Y = 8.270 - 0.758 (pH) - 0.002 (EC) + 0.082 ($CaCO_3$) - 0.479 (LIME) + 0 .068 (CEC) + 1.141 (OM) - 0.027 (Clay)	5
0.112	المتبقي Y = 178.957 - 8.130 (pH) - 0.004 (EC) - 1.246 ($CaCO_3$) + 4.164 (LIME) + 0.086 (CEC) + 2.496 (OM) -0.688 (Clay)	6

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

5.2. أشكال الزنك الكيميائية في الترب المدروسة:

نلاحظ من الجدول (5) أن توزع الأشكال الكيميائية للزنك يكون على النحو التالي: المتبقي (98.352 mg/kg)> المرتبط بأوكسيد الحديد والمنغنيز(31.060 mg/kg)> المرتبط بالمادة العضوية (mg/kg 3.277)> المرتبط بالكربونات (3.059 mg/kg)> القابل للتبادل (0.580 mg/kg). تراوح تركيز الزنك القابل للتبادل بين 0.129 و(2.841 mg/kg) بمتوسط (0.580 mg/kg) يتضمن هذا الشكل (الزنك) المدمص بشكل ضعيف بالتربة وبشكل خاص الزنك المرتبط بسطح التربة بقوى الكتروستاتية، (الزنك الذي يتحرر بعملية التبادل الأيوني) ويعد هذا التركيز أقل مما يحتاجه النبات(Shuman, 1991) لذلك من المتوقع أن يعتمد النبات على الاشكال الأخرى من الزنك (المرتبط بالكربونات، المرتبط بالمادة العضوية) لتلبية احتياجاته وهذا يتوافق مع دراسات عديدة (Minkina, et al, 2008 ، Chen, et al, 2009).

جدول 5. أشكال الزنك الكيميائية مقدرة بـ ملغ/ كغ في الترب المدروسة

Residual	Organic bound	Oxide bound	Carbonate bound	Exchangeable	Total	الموقع	منطقة الاستقرار
89.48	2.84	18.05	0.90	0.39	111.65	المشرفة المستورة	الاولى
90.25	1.62	11.33	0.48	0.27	103.95	الأشرفية	
107.24	6.87	60.21	3.08	0.33	177.74	تلدهب	
102.21	9.92	67.80	6.69	1.67	188.29	رباح	
72.25	7.29	56.93	13.43	2.70	152.60	عرقايا	
84.18	3.00	14.47	0.54	0.85	103.04	القبو	
101.14	3.96	31.23	8.57	0.63	145.53	شين	
103.86	1.58	27.38	1.47	0.45	134.74	قطينة	
86.55	2.62	14.12	0.48	0.68	104.45	مريمين	
116.93	4.01	24.92	1.34	0.27	147.46	المرانة	
120.98	12.30	166.92	17.64	0.67	318.51	خربة غازي	
30.69	3.72	28.00	1.69	1.19	65.30	نعرة	
78.77	7.99	38.37	2.32	0.25	127.69	خربة التين	
77.87	8.54	33.39	0.81	0.44	121.06	خربة السودا	
110.75	3.02	16.00	1.54	0.81	132.12	حدية	
73.83	2.79	25.72	2.29	0.26	104.90	كفرام	
114.10	11.07	56.07	4.91	0.50	186.65	الصويري	
172.46	1.04	13.80	0.70	0.12	188.11	تلبيسة	
110.52	3.01	27.23	0.84	0.60	142.21	كفرلاها	
131.49	5.53	9.94	0.68	0.89	148.53	فاحل	
111.10	5.65	28.57	2.48	1.04	148.83	ضهر القصير	
92.71	0.78	3.28	2.80	1.66	101.23	المختارية	
30.69- 172.46	**0.78- 12.30**	**3.28- 166.92**	**0.478- 17.64**	**0.123- 2.71**	**65.3- 318.51**	RANGE	
(%69.08) 99.06	**(%3.46) 4.96**	**(%24. 53) 35.17**	**(%2.34) 3.44**	**(%0.53) 0.76**	**143.39**	AVERAGE	
61.09	0.96	21.02	0.62	0.38	84.07	فيروزة	الثانية
142.83	16.55	191.48	37.36	0.27	388.49	المشرفة	
78.02	1.04	14.25	0.51	0.40	94.22	دير فول	
93.82	2.94	10.78	0.86	0.30	108.70	الديابية	
82.39	0.92	24.46	0.76	0.46	108.99	زيدل	
67.04	2.03	61.29	9.47	0.46	140.29	جديدة الشرقية	
73.03	2.00	8.35	0.71	0.34	84.43	شنشار	
289.55	4.44	163.21	0.63	2.84	460.66	شنشار 2	
77.99	2.28	13.10	1.04	0.83	95.24	ابل	
104.99	2.83	20.04	1.37	0.19	129.42	نوى	
108.62	2.63	14.92	3.26	0.24	129.67	خلفة	
61.09- 289.55	**0.92- 16.55**	**8.35- 191.48**	**0.51- 37.35**	**0.19- 2.84**	**84.07 - 460.66**	RANGE	
(%64.66) 107.22	**(%2.12) 3.51**	**(%29.76) 49.35**	**(%3.10) 5.14**	**(%0.37) 0.61**	**165.83**	AVERAGE	
183.29	4.72	26.67	1.73	0.42	216.83	المخرم 1	الثالثة
50.84	1.05	14.75	1.14	0.41	68.18	المخرم	
93.81	0.81	10.60	0.58	0.22	106.02	الحراكي	
105.74	1.27	28.10	8.18	0.24	143.53	الجابرية	
117.86	0.94	13.26	0.36	0.29	132.71	السنكري	
106.01	3.21	11.62	1.12	1.12	123.07	القصير	
47.57	2.44	14.27	1.98	0.28	66.54	أعور	
112.71	1.00	14.65	0.91	0.74	130.01	جب الجراح	
76.62	1.49	25.06	0.85	0.35	104.36	المنزول	
166.03	1.45	17.38	2.11	0.33	187.31	هبرة غربية	
47.56- 183.29	**0.81- 4.72**	**10.50- 28.10**	**0.36- 8.18**	**0.22- 1.12**	**66.54- 216.83**	**RANGE**	
(%82.94)106.05	**(%1.44) 1.84**	**(%13.79) 17.63**	**(%1.48) 1.90**	**(%0.34) 0.44**	**127.86**	**AVERAGE**	
102.65	1.86	10.43	0.42	0.44	115.80	حسياء	الرابعة
118.31	1.74	36.55	6.01	0.35	162.96	المسعودية	
63.69	1.45	10.36	1.01	0.28	76.79	المضابع	
77.71	1.15	11.47	1.62	0.38	92.33	جندر	
99.07	1.06	12.56	0.96	0.13	113.77	شمسين	
67.80	0.79	9.02	0.96	0.24	78.80	الصايد	
99.28	1.89	8.46	0.26	0.51	110.40	رغاما	
135.29	1.74	11.49	1.96	0.23	150.71	أم التبابير	
77.19	1.07	9.20	0.76	0.28	88.50	الشعيرات	
63.68- 135.29	**0.79- 1.89**	**8.46- 36.55**	**0.26 - 6.0084**	**0.13- 0.51**	**76.79- 162.96**	**RANGE**	
(%84.94) 93.44	**(%1.29) 1.42**	**(%12.07) 13.28**	**(%1.41) 1.55**	**(%0.29) 0.32**	**110.01**	**AVERAGE**	
31.01	0.87	23.93	0.74	0.15	56.70	ابو رجمين	الخامسة
123.60	0.35	18.97	2.13	0.53	145.58	القريتين 1	
23.20	5.69	81.36	5.71	0.38	116.35	حوارين	
29.78	1.22	23.61	1.87	1.37	57.85	الصوانة	
87.86	2.28	22.46	0.70	0.43	113.72	السخنة	
162.68	1.86	31.65	2.15	0.35	198.70	وادي أحمر	
84.44	2.17	18.09	1.96	0.34	107.01	صدد	
23.20- 162.68	**0.35- 5.69**	**18.09- 81.36**	**0.70- 5.71**	**0.15- 1.37**	**56.7- 198.7**	**RANGE**	
(%68.17) 77.51	**(%1.81) 2.06**	**(%27.65) 31.44**	**(%1.92) 2.18**	**(%0.45) 0.51**	**113.70**	**AVERAGE**	
23.20- 289.55	**0.35- 16.55**	**3.28- 191.48**	**0.26- 37.35**	**0.12- 2.84**	**56.7- 460.66**		**RANGE**
(%72.14) 98.35	**(2.40) 3.28**	**(%22.78) 31.06**	**(%2.24) 3.06**	**(%0.43) 0.58**	**136.33**		**AVERAGE**

جدول 4. بعض الخصائص الفيزيو- كيميائية للترب المدروسة

	التحليل الميكانيكي غ/ 100غ			TOM%	cec	active		EC (1:5)			
النسيج	السلت	الطين	الرمل		(meq/100g)	lime%	كربونات %	µS/cm	pH	الموقع	منطقة الاستقرار
طينية لومية	41.53	39.04	19.44	1.09	37.38	1.47	2	146.6	7.97	مستورة	الاولى
طينية	26.47	50.40	23.14	1.21	49.38	4.41	4.98	148	8.3	الاشرفية	
طينية لومية	44.29	33.97	21.74	1.55	27.13	1.23	6.19	185	8.1	تل دهب	
طينية لومية	35.96	36.06	27.98	1.79	29.75	اثار	اثار	86.7	6.78	رباح	
لومية	31.50	23.73	44.77	6.55	25.13	2.94	8.25	278	7.63	عرقاية	
طينية	28.38	41.38	30.23	1.62	23.75	2.21	3.01	52.6	6.91	قبو	
طينية	20.70	43.06	36.24	1.21	33.75	اثار	اثار	101	7.29	شين	
طينية	28.65	44.38	26.97	2.07	38.13	8.58	10.82	8.8	8.15	قطينة	
طينية	28.46	57.02	14.53	1.16	25.25	1.47	2.08	115.5	6.72	مريمين	
طينية لومية	36.82	35.87	27.31	0.88	32.88	3.92	5.11	72	7.87	مرانة	
لومية	41.16	15.54	43.30	6.07	29.38	2.21	6.08	620	8.29	خربة غازي	
طينية لومية	38.95	36.46	24.59	3.28	33.75	4.17	6.05	89	8.1	نعرة	
لومية	53.86	22.16	23.98	2.19	29.13	1.23	2.06	139.4	8.13	خربة التين	
طينية	41.21	57.29	1.50	0.69	28.13	اثار	اثار	82.8	7.38	خربة السودا	
طينية لومية	28.69	34.01	37.31	0.69	23.75	اثار	اثار	41.4	6.63	حدية	
طينية لومية	46.24	36.07	17.69	1.00	21.50	1.23	2.58	230	8.04	كفرام	
رملية طينية لومية	25.55	26.17	48.28	4.52	29.00	0.73	1.03	155.9	7.61	الصويري	
طينية لومية	28.39	33.66	37.95	1.09	37.88	11.76	12.34	96.8	8.2	تليبسة	
سلتية طينية	54.01	41.77	4.22	1.07	25.88	4.90	8.00	124.8	7.72	كفرلاها	
لومية	43.86	26.42	29.73	1.02	23.63	اثار	اثار	118.3	7.32	فاحل	
لومية	36.53	27.24	36.23	1.43	31.63	اثار	0.13	126.4	6.12	ضهر القصير	
طينية لومية	33.42	37.12	29.46	0.95	32.50	15.19	23.71	146.4	8.34	مختارية	
طينية	30.90	47.48	21.63	0.78	29.13	2.21	2.90	362	8.17	فيروزة	الثانية
رملية طينية	15.58	36.46	47.95	5.33	35.00	2.94	4.33	152	8.21	مشرفة	
طينية	18.19	58.32	23.49	0.43	31.88	2.21	3.71	105.5	8.54	دير فول	
طينية لومية	35.97	36.58	27.45	1.12	28.13	1.72	2.99	137	8.9	ديابية	
طينية	28.32	50.05	21.63	1.16	32.63	6.13	9.59	131.4	8.34	زيدل	
رملية طينية لومية	15.34	26.18	58.47	4.31	25.38	5.15	9.28	260	8.39	جديدة	
طينية	23.76	63.99	12.25	2.31	36.50	8.82	12.37	153.7	8.48	شنشار	
طينية لومية	30.41	36.09	33.51	2.38	20.50	7.60	22.68	132	8.18	شنشار1	
طينية لومية	30.92	31.02	38.06	1.57	29.00	2.70	5.67	378	8.18	ابل	
طينية لومية	15.14	24.33	60.53	2.07	25.00	3.19	5.06	119	8.43	نوى	
رملية طينية لومية	40.89	31.28	27.82	3.28	27.50	4.17	9.74	1606	7.69	خلفة 2	
طينية لومية	38.40	36.97	24.63	4.47	31.88	3.92	9.28	188.7	8.12	مخرم 1	الثالثة
رملية طينية لومية	15.74	26.34	57.93	2.14	15.00	8.09	24.60	282	8.07	مخرم فوقاني	
طينية	23.00	48.15	28.84	1.79	19.75	6.37	16.91	220	8.43	الحراكي	
طينية	30.91	51.62	17.46	2.43	38.75	7.35	11.34	294	7.99	جابرية	
سلتية لومية	55.97	21.98	22.04	1.91	20.88	14.95	36.90	300	8.6	سنكري	
طينية لومية	45.85	31.69	22.46	1.64	20.63	8.09	19.79	128.1	8.54	القصير	
رملية طينية لومية	22.63	32.29	45.08	0.69	8.00	11.03	58.82	115.5	8.59	الاعور	
سلتية طينية لومية	53.32	36.66	10.01	1.38	22.50	8.33	21.65	128.1	8.38	جب الجراح	
طينية لومية	46.49	32.13	21.38	1.47	24.50	0.73	1.55	491	7.91	منزول	
لومية	48.42	22.02	29.56	2.98	17.88	11.76	22.99	147	8.26	هبرة غربية	
لومية	46.31	27.37	26.32	0.62	30.13	2.94	4.12	143.3	8.51	حسياء	الرابعة
لومية	40.93	24.15	34.91	4.83	23.88	6.86	20.62	199.7	8.22	مسعودية	
رملية طينية لومية	17.80	37.74	44.46	2.52	24.25	12.50	37.43	391	8.29	مضابع1	
طينية لومية	46.04	32.84	21.13	2.12	21.88	6.37	19.25	270	8.29	جندر	
طينية لومية	27.88	37.61	34.51	1.76	17.13	7.35	31.02	117.2	8.38	شمسين	
طينية لومية	40.50	30.48	29.02	3.17	16.00	12.25	47.06	136	8.5	صايد	
طينية لومية	40.80	32.74	26.45	1.60	27.00	7.84	15.51	127.2	8.35	رغاما	
طينية	40.85	48.11	11.04	0.52	16.25	5.39	12.37	202	8.48	ام التبابير	
طينية	20.34	50.44	29.21	1.72	24.00	8.58	23.71	109.6	8.49	الشعيرات	
لومية	32.47	25.58	41.95	0.53	9.75	14.70	62.39	323	8.68	ابو رجمين	الخامسة
طينية لومية	30.29	30.89	38.82	0.69	14.25	11.03	54.55	668	8.5	قريتين1	
رملية طينية لومية	22.92	30.66	46.41	4.60	17.63	16.66	61.88	2560	7.95	حوارين	
رملية طينية	17.58	37.78	44.63	0.86	10.63	13.97	51.34	164	8.69	الصوانة	
طينية	33.02	43.28	23.71	3.10	16.25	17.89	49.20	569	8.36	السخنة	
طينية لومية	40.76	31.69	27.55	2.50	27.50	10.54	34.22	402	8.02	وادي احمر	
لومية	38.02	26.46	35.51	1.81	17.75	12.01	51.34	709	8.36	صدد	
	55.97	63.99	60.53	6.55	49.38	17.89	62.39	2560.00	8.90		MAX
	15.14	15.54	1.50	0.43	8.00	0.73	0.13	8.80	6.12		MIN
	33.85	36.07	30.07	2.06	25.82	6.83	18.38	272.67	8.07		AVERAGE

3.3. التحاليل المخبرية:

تم إجراء بعض التحاليل الفيزيائية والكيميائية على عينات الترب المدروسة ومنها:

التحليل الميكانيكي وتحديد قوام التربة وفق طريقة الهيدرومتر(Bouyoucos, 1962; Day, 1965; FAO, 1974). تقدير pH التربة: تم قياسه في معلَّق تربة: ماء 2.5:1 باستخدام جهاز قياس الـ pH meter-(McKeague, 1978 ; McLean, 1982) - قياس الموصلية الكهربائية:(EC) تم تقديرها في مستخلص مائي للتربة (5:1) بواسطة جهاز الموصلية الكهربائية (Richards, 1954). تقدير الكربونات الكلية: أجري القياس بطريقة الكالسيميتر(Bascom, 1961). تقدير الكلس الفعال (ACTIVE LIME) بطريقة دورينو غاليه (Drouineau, 1942). تقدير المادة العضوية (TOM): بطريقة الأكسدة الرطبة بديكرومات البوتاسيوم في وسط شديد الحموضة (Walkley and Black, 1934). تقدير سعة التبادل الكاتيوني (CEC): تم قياسها بطريقة كلور الكالسيوم (Chapman, 1965).

3.4. الاشكال الكيميائية للزنك:

تم تقدير الشكل الكلي للزنك (TOTAL) عن طريق الهضم بالمايكرويف بإضافة الماء الملكي، وتم تقدير أشكال الزنك المدروسة بطريقة الاستخلاص التسلسلي وفق طريقة (Tessier et al, 1979) وذلك لتوفر امكانية تطبيق هذه الطريقة دون غيرها من الطرق الأحدث منها. ويبين الجدول (3) الكواشف المستخدمة في الاستخلاص الانتقائي وظروف التجربة حسب (Tessier et al, 1979) ، ثم تم قياس أشكال الزنك على جهاز الامتصاص الذري.

جدول 3. الكواشف المستخدمة في الاستخلاص الانتقائي وظروف التجربة حسب (Tessier et al, 1979)

الشكل المستخلص	الكاشف	ظروف التجربة
المتبادل (EXC)	8 ml of 1 mol L^{-1} $MgCl_2$ (pH 7)	1 h at 25°C
المرتبط بالكربونات (CAR)	8 ml of 1 mol L^{-1} NaOAc (pH 5 with acetic acid)	5 h at 25°C
المرتبط بأكسيد الحديد والمنغنيز (Fe/Mn)	20 ml of 0.04 mol L^{-1} $NH_2OH{\cdot}HCl$ in 25% w/v HOAc (pH~2)	6 h at 96°C
المرتبط بالمادة العضوية (OM)	3 ml of 0.02 mol $L^{-1}HNO_3$+ 5 ml of 30% m/v H_2O_2	2 h at 85°C
	+3 ml of 30% m/v H_2O_2	3 h at 85°C
	+5 ml of 3.2 mol L^{-1} NH_4OAc	30 min at 25°C

Ac: acetic acid

وتم حساب الجزء المتبقي (RES) وذلك عن طريق طرح الأشكال المستخلصة من الزنك (المتبادل، المرتبط بالكربونات، المرتبط أوكسيد الحديد والمنغنيز، المرتبط بالمادة العضوية) من الشكل الكلي (TOTAL).

رابعاً: الدراسة الاحصائية:

تم دراسة علاقات الارتباط بين أشكال الزنك والخصائص الأساسية للترب المدروسة وذلك باستخدام برنامج SPSS، وتم دراسة معادلات الانحدار المتعدد وذلك لتقييم تأثير المتغير المستقل على المتغير التابع.

خامسا": عرض ومناقشة النتائج:

تم دراسة علاقات الارتباط بين أشكال الزنك والخصائص الأساسية للترب المدروسة وذلك باستخدام برنامج SPSS، وتم دراسة معادلات الانحدار المتعدد وذلك لتقييم تأثير المتغير المستقل على المتغير التابع.

5.1. الخصائص الأساسية للترب المدروسة:

يتبين من معطيات الجدول (4) بأن pH العينات تراوح بين 6.12 و 8.69 وكانت معظم العينات ذات pH قلوي خفيف، كما يبين الجدول (4) أن تركيز الكربونات الكلية والكلس الفعال (Active Lime) اختلف اختلافاً كبيراً حيث كان محتوى العينات منخفضاً أو غير ملحوظ في بعض العينات (شين، فاحل، ضهر القصير) في حين وصل التركيز الى 63% (ابو رجمين)، كما نلاحظ من نفس الجدول بأن الترب المدروسة كانت عموماً غير مالحة الى خفيفة الملوحة باستثناء بعض ترب منطقة الاستقرار الخامسة، كما تراوحت قيم سعة التبادل الكاتيوني (CEC) بين 9 و49 meq / 100g جدول (4). تظهر نتائج تحليل المادة العضوية (TOM) جدول (4) في العينات المدروسة اختلافاً واضحاً بين العينات ففي حين لم ترتفع عن 1% في بعض العينات، نلاحظ أنها وصلت الى 6.56% في تربة عرقايا وكانت معظم العينات متوسطة المحتوى من المادة العضوية. كما نلاحظ من الجدول (4) أن نسيج التربة المدروسة قد تراوح بين المتوسط والثقيل في جميع العينات.

جدول 2. أماكن أخذ العينات

الموقع	المحصول المزروع	الري	المنطقة البيومناخية
مستورة	فستق	مروي	منطقة الاستقرار الأولى
الاشرفية	دوار الشمس	مروي	منطقة الاستقرار الأولى
تل دهب	قمح	بعل	منطقة الاستقرار الأولى
رباح	بور	بعل	منطقة الاستقرار الأولى
عرقاية	خضار	مروي	منطقة الاستقرار الأولى
قبو	زيتون	بعل	منطقة الاستقرار الأولى
شين	خضار	مروي	منطقة الاستقرار الأولى
قطينة	خضار	مروي	منطقة الاستقرار الأولى
مريمين	زيتون	بعل	منطقة الاستقرار الأولى
مرانة	تين	بعل	منطقة الاستقرار الأولى
خربة غازي	بور	بعل	منطقة الاستقرار الأولى
نعرة	زيتون	بعل	منطقة الاستقرار الأولى
خربة التين	بور	بعل	منطقة الاستقرار الأولى
خربة السودا	قمح	بعل	منطقة الاستقرار الأولى
حدية	تفاح	مروي	منطقة الاستقرار الأولى
كفرام	تفاح	مروي	منطقة الاستقرار الأولى
الصويري	تفاح	بعل	منطقة الاستقرار الأولى
تلبيسة	قمح	بعل	منطقة الاستقرار الأولى
كفرلاها	بطاطا	مروي	منطقة الاستقرار الأولى
فاحل	زيتون	بعل	منطقة الاستقرار الأولى
ضهر القصير	أشجار حراجية	بعل	منطقة الاستقرار الأولى
مختارية			منطقة الاستقرار الأولى
فيروزة	خضار	مروي	منطقة الاستقرار الثانية
مشرفة	زيتون	بعل	منطقة الاستقرار الثانية
دير فول	لوز	بعل	منطقة الاستقرار الثانية
ديابية	أشجار حراجية	بعل	منطقة الاستقرار الثانية
زيدل	فول	بعل	منطقة الاستقرار الثانية
جديدة	زيتون	مروي	منطقة الاستقرار الثانية
شنشار	زيتون	مروي	منطقة الاستقرار الثانية
شنشار ١	قمح	بعل	منطقة الاستقرار الثانية
ابل	زيتون	مروي	منطقة الاستقرار الثانية
نوى	زيتون	بعل	منطقة الاستقرار الثانية
خلفة ٢	بطاطا	مروي	منطقة الاستقرار الثانية
مخرم ١	عنب	مروي	منطقة الاستقرار الثالثة
مخرم فوقاني	زيتون	بعل	منطقة الاستقرار الثالثة
الحراكي	زيتون	بعل	منطقة الاستقرار الثالثة
جابرية	بور	بعل	منطقة الاستقرار الثالثة
سنكري	شعير	بعل	منطقة الاستقرار الثالثة
القصير	زيتون	مروي	منطقة الاستقرار الثالثة
الاعور	كرمة	مروي	منطقة الاستقرار الثالثة
جب الجراح	لوز	بعل	منطقة الاستقرار الثالثة
منزول	ملفوف	مروي	منطقة الاستقرار الثالثة
هبرة غربية	بور	بعل	منطقة الاستقرار الثالثة
حسياء	بامياء	مروي	منطقة الاستقرار الثالثة
مسعودية	زيتون	مروي	منطقة الاستقرار الرابعة
مضابع١	خضار	مروي	منطقة الاستقرار الرابعة
جندر	لوز	بعل	منطقة الاستقرار الرابعة
شمسين	شعير	بعل	منطقة الاستقرار الرابعة
صايد	لوز	بعل	منطقة الاستقرار الرابعة
رغاما	لوز	مروي	منطقة الاستقرار الرابعة
ام التبابير	قمح	مروي	منطقة الاستقرار الرابعة
الشعيرات	زيتون	بعل	منطقة الاستقرار الرابعة
ابو رجمين	بور	بعل	منطقة الاستقرار الخامسة
قريتين١	رغل	بعل	منطقة الاستقرار الخامسة
حوارين	زيتون	مروي	منطقة الاستقرار الخامسة
الصوانة	شعير		منطقة الاستقرار الخامسة
السخنة	زيتون	مروي	منطقة الاستقرار الخامسة
وادي احمر	بور	بعل	منطقة الاستقرار الخامسة
صدد	خضار	مروي	منطقة الاستقرار الخامسة

الزنك في المناطق الحارة (Slaton et al., 2005; Prasad 2006;)، وفي بلدان العالم الثالث بسبب ازدياد الطلب (Fageria et al., 2011) على الغذاء لتلبية احتياجات السكان المتزايدة. يستمر نقص الزنك الى ان يكون احد العناصر الأساسية في تحديد الانتاج في عدة أجزاء من البلاد (Chaudhary et al. 2007). وهو يعرف الان كعامل الخطر الخامس في تطوير البلدان الاسيوية (Anonymous 2007)، ويؤدي نقص الزنك في التربة الى نقص الزنك في الحبة والقشة مما يؤدي الى تغذية سيئة للبشر والحيوانات وهذا الموضوع حصل على اهتماما كبيراً مؤخراً (Schardt, 2006)، حيث وجد (Hambridge et al., 1986) أن نقص الزنك في النظام الغذائي للإنسان يؤدي الى نمو ضعيف (إعاقة) عند الأطفال. يفيد المحتوى الكلي للزنك في العديد من التطبيقات الجيوكيميائية، لكن زراعياً يكون أشكال العنصر وخاصة (المتاح) هو الأكثر أهمية (Ashraf et al., 2012). يتوزع الزنك الكلي على خمسة أشكال في التربة وهي: الذائب بالماء، المتبادل، المرتبط بالكربونات، المرتبط بأكسيد الحديد والمنغنيز، المرتبط بالمادة العضوية، المتبقي المرتبط بالمعادن الأولية (Saffari ., 2009). تفيدنا هذه الاشكال بمعلومات عن العمليات البيولوجية والجيولوجية والكيميائية التي تحدث لعنصر الزنك في التربة وهذا يفيد في التنبؤ بإتاحة الزنك للنبات. حيث يكون المتبقي والمرتبط بأوكسيد أكثر ثباتاً وغير متاح بيولوجياً للنبات، بينما الذائب والمتبادل أكثر ذوبانية والاكثر اهميه للنبات كون النبات يمتص الزنك على صورته الأيونية (Rahmani et al., 2012). يرتبط محتوى الترب من الزنك بالقوام ويكون أقل ما يمكن بالترب الرملية، وتلاحظ تراكيزه المرتفعة في الترب الكلسية والعضوية. يتحكم بالتركيز الأولي للزنك كل من المادة الأصل وعملية تشكل التربة والمادة العضوية (OM organic matter)، كما يساهم الطين بشكل معنوي (خاصة الفيرميكوليت والجبسيت) في محتوى التربة من الزنك (Vega et al, 2007). على الرغم من اعتبار الزنك متحرك في معظم الترب، يبدي الطين و OM القدرة على الاحتفاظ به بقوة وخاصة بالترب المعتدلة والقلوية (Peganova and Edler, 2004)، ويعد (DOM dissolved organic matter) عامل مهم في التأثير على حركية الزنك عند pH= 7- 7.5 (Wong et al., 2007). يضبط الفوسفور والطين عدم حركية الزنك في التربة (Kumpiene et al., 2008)، ووجدت أن 60% من الزنك يضبط من قبل الطين (Kabata-Pendias and Krakowiak, 1995).

ثانياً: مبررات البحث والهدف منه:

تتأثر نسبة كل شكل من أشكال الزنك من المحتوى الكلي للترب بالخصائص الاساسية للترب مثل الـ pH وسعة التبادل الكاتيوني والقوام والمادة العضوية، وتركز أغلب الدراسات في سوريا على المحتوى الكلي وعلى الجزء المستخلص بـ DTPA ، ففي دراسة قام بها (شمشم، 2011) لدراسة محتوى الترب من محافظة حمص من الزنك المتاح المستخلص بـ DTPA، وجد أن تركيز الزنك المتاح في مناطق الاستقرار الخمسة في المحافظة كان (0.64 ، 0.43، 0.42، 0.39، 0.15) مغ/ كغ بدءً من منطقة الاستقرار الأولى. بينما تركز دراسات قليلة على أشكال الزنك لذلك فمن المهم فهم أشكال الزنك وتحولاته في التربة ومقدرته الكامنة على تلبية متطلبات النبات. لذلك كان الهدف من هذا البحث هو دراسة الأشكال الكيميائية للزنك في ترب مختارة من محافظة حمص السورية ودراسة تأثير الخصائص الاساسية للتربة على أشكال الزنك المدروسة.

ثالثا": مواد البحث وطرائقه:

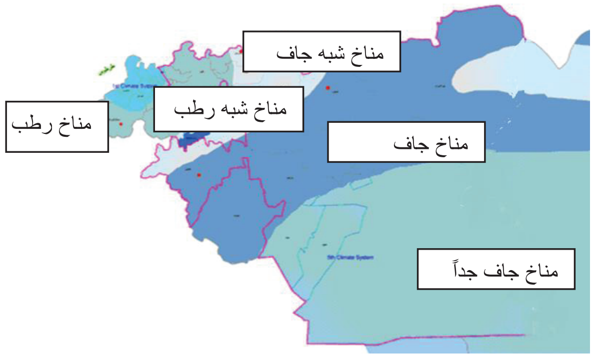
3.1. منطقة الدراسة:

يشمل موقع الدراسة بعض قرى من مناطق الاستقرار الخمسة من محافظة حمص والتي تم منها جمع عينات التربة. وفيما يلي أهم المعطيات المناخية لمناطق الاستقرار الخمس في محافظة حمص، ومساحة كلٍّ منها، وما تمثله من مساحة القطر العربي السوري، (دائرة الإحصاء والتخطيط- مديرية زراعة حمص، 2014) حيث يبين الجدول (1) أهم المعطيات المناخية لمناطق الاستقرار الخمس في محافظة حمص ومساحة كلٍّ منها (مديرية الاحصاء والتخطيط – مديرية زراعة حمص، 2014).

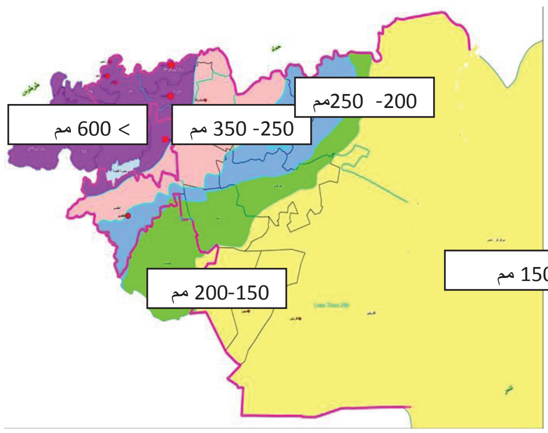
جدول 1. أهم المعطيات المناخية والمساحية في محافظة حمص

منطقة الاستقرار الزراعي	المساحة (ألف هكتار) والنسبة المئوية	معدل الهطول المطري ملم/عام	أعلى درجة الحرارة	أدنى درجة حرارة
الأولى	2701 14,6%	أكثر من 600 350- 600	41,2	3,5-
الثانية	2475 13,3%	250- 350	42,4	4,9-
الثالثة	1303 7,15%	200- 250	43,9	6,3-
الرابعة	1830 9,9%	150- 200	45,3	7,4-
الخامسة	10209 55,1%	أقل من 150	47,5	8,9-

ويبين الشكلين التاليين المناطق المناخية ومعدلات الأمطار في محافظة حمص



شكل 1. المناطق المناخية في محافظة حمص



شكل 2. معدلات الأمطار في محافظة حمص

3.2. جمع عينات التربة:

لتحقيق هدف الدراسة تم جمع 59 عينة تربة مختلفة بخواصها الفيزيائية والكيميائية وذلك لتغطية معظم مناطق الاستقرار المناخية الخمسة من محافظة، وذلك من الطبقة السطحية (0-25 cm)، في الفترة ما بين 1/1/ 2013 – 1/6/2013 حيث تم تجفيف العينات تجفيفاً هوائياً و استبعاد الحجارة و الحصى وبعدها نخلت التربة بمنخل أبعاد ثقوبه 2mm ويبين الجدول (2) أماكن أخذ العينات.

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أشكال الزنك وعلاقته بالخصائص الاساسية للتربة في ترب من محافظة حمص

Fractionation of Zinc and their Association with Soil Properties in Soils of governorate Homs

سمير محمد درويش شمشم، ريم فاروق نصرا*

Sameer Shamsham, Reem Nassra*

[1]قسم التربة واستصلاح الأراضي كلية الزراعة، جامعة البعث، سوريا.

Dep.,Soil Sciences and land Reclamation, Faculty of Agriculture Al-Baath Uni, Syria.

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الملخص

يعد فهم توزع الزنك في التربة مهم من أجل ادارة فعالة لمصادر التسميد في العالم ولتدارك حدود النقص بعنصر الزنك الواجب توافرها للمحاصيل والانسان. تقيم هذه الدراسة أشكال الزنك الكيميائية وتوزعها في ترب مختارة من محافظة حمص. استخدمت مخططات الاستخلاص التسلسلي لتجزئة الزنك الى الشكل المتبادل، المرتبط بالكربونات، المرتبط بأوكسيد الحديد والمنغنيز، المرتبط بالمادة العضوية، والشكل المتبقي. تراوح تركيز الزنك الكلي بين56.7 الى 460.66 مغ/ كغ وبمتوسط 136.33 مغ/ كغ، وكان ترتيب أشكال الزنك كنسبة مئوية من الشكل الكلي بالاعتماد على المتوسط: المتبقي (72.14%) > المرتبط بأوكسيد الحديد والمنغنيز(% 22.78)> المرتبط بالمادة العضوية(2.40) > المرتبط بالكربونات (% 2.24)> القابل للتبادل (0.43%). كانت نسبة الأشكال المتاحة من الزنك عالية في ترب منطقة الاستقرار الثانية (35.35%) ومنخفضة في الرابعة (15.057%). تظهر علاقات الارتباط بأن الزنك الكلي والمرتبط بالكربونات والمرتبط بأوكسيد الحديد والمنغنيز والمرتبط بالمادة العضوية يزداد مع زيادة المادة العضوية، وأن الزنك المرتبط بالمادة العضوية ينخفض مع زيادة الـ pH (r =-0.353) والكربونات الكلية (r = -0.350)، كما تظهر معادلات الانحدار وجود معنوية بين أشكال الزنك (الكلي، المرتبط بالكربونات، المرتبط بأوكسيد الحديد والمنغنيز، المرتبط بالمادة العضوية) والخصائص المدروسة في ترب من محافظة حمص.

الكلمات المفتاحية : الأشكال الكيميائية، عامل الحركية، الانحدار، الزنك.

Abstract

Understanding the distribution of zinc (Zn) fractions in soils is important for effective and efficient management of the fertilizer resources given world-wide, limitations of crop production and food quality by insufficient Zn. This study was undertaken to evaluate the chemical speciation and distribution of Zn in soils of Homs Governorate. Sequential extraction scheme was used to fractionate Zn into exchangeable, bound to carbonate, organically bound, bound to manganese (Mn) and iron (Fe) oxide, and residual forms. Total soil Zn ranged from 56.7 to 460.66 mg kg-1 with an average of 136.33 mg kg-1. The distribution of Zn fractions in the soils on the basis of average concentrations was in the order: residual (72.14%) > oxide bound (22.78%) > organic bound (2.40%) > carbonate bound (2.24%) > exchangeable (0.43%) Data shows that percentage of potentially available fraction of Zn was highest in soils of second agricultural stability areas (35.35%) and lowest in fourth (15.057 %). Correlation analysis showed that total Zn, bound to carbonate, bound to manganese (Mn) and iron (Fe) oxide and organically bound increased with soil organic matter, Zn bound to organic decreased with pH (r = -0.353), and calcium carbonate (r = - 0.350). Linear regression equation showed the significant R2 between the Zn fractions(Total, bound to carbonate, organically bound, bound to manganese (Mn) and iron (Fe) oxide with studied soil properties in soils of Homs Governorate.

Keywords: Chemical fractionation, mobility factor, Regression, Zinc.

أولاً: المقدمة والدراسة المرجعية:

يعد الزنك من العناصر الصغرى الضرورية للنبات والذي لا تقل أهميته عن أي عنصر ضروري للنبات، يدخل الزنك في تركيب جدران الخلايا، كما يزيد من تركيز الفوسفور في الأجزاء الهوائية المتشكلة (Farshid Aref, 2010)، ويلعب دورا في كمية ونوعية المحصول (Chidanandappa et al., 2008)، وله دور مهم في اصطناع الأوكسينات وتركيب البروتين والكلوروفيل، كما يدخل في تركيب أكثر من 300 أنزيم مثل: dehydrogenases, adolase, isomerase, proteinases, peptiodases, phosphohydrolases, carbonic-anhydrase and superoxide dismutase (FAO/WHO/IAEA, 1996; Haung et al., 2010)، يؤدي نقص الزنك الى تأخر النضج حيث ينتشر نقص

* Corresponding author. e-mail: rimannn@gmail.com

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Hunt, J. 1996. Petroleum Geochemistry and Geology. 2nd Ed., H. W. Freeman and Company, New York.

- Chapter in a book:

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- Periodicals:

Sexton, P. F., Wilson, P. A.,and Pearson, P. N., 2006. Paleoecology of Late Middle Eocene Planktonic Foraminifera and Evolutionary Implication, Marine Micropaleontology, 60(1): 1-16.

- Conferences and Meetings:

Huber, B. T. 1991. Paleogene and Early Neogene Planktonic Foraninifer Biostratigraphy of Sites 738 and 744, Kerguelen Plateau (southern Indian Ocean). In: Barron, J., Larsen, B., et. al. (Eds.), Proceedings of the Ocean Drilling Program. Scientific Results, vol. 119. Ocean Drilling Program, College station, TX, pp. 427-449.

- Dissertations:

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The Hashemite University,

P.O. Box 150459, Zarqa, 13115, Jordan.
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Fax: 00962-5-3826823
E-Mail: jjees@hu.edu.jo
http:// jjees.hu.edu.jo/

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