Monitoring of Water Quality for Agriculture Purposes Using High Resolution Images (ASTER): A Case Study from Egypt

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ABSTRACT

Life of Egypt is substantially linked to the Nile River. The Nile River is the principal source of water in Egypt which is used for purposes such as agriculture, drinking, electricity generation and industry. The Water Quality Index (WQI) is a valuable and simple tool for announcing and explaining massive dataobtained from any body of water. Remote sensing can be a useful tool in the water quality monitoring. WQI is applied, in thispaper, to evaluate suitability of Nile water for irrigation usage, in Rosetta River Nile branch, El-Beheira governorate, Egypt. Water samples were collected from six various sites about 65 km stretch along Rosetta River Nile branch at almost equal distances, starting from Kafr El-Zayat city to Idfina Barrage. Polyethylene plastic bottles (1 Liter capacity) were used to collect water samples. Samples were assessed for eight (8) Chemical parameters, namely pH, electrical conductivity, Sodium, Potassium, Calcium, Magnesium, Bicarbonate and Chlorides. The regression analysis is used to investigate the correlation between WQI and remote sensing data (ASTER images). The results showed that the water quality index were mostly good for irrigation purposes according to FAO guidelines (WQI values between 50-100), except for site 1 which had a poor class (WQI values between 100-200) because of the artificial pollution at it. The electrical conductivity and sodium concentration were the most important characteristics affecting the calculated water quality index of the study area. Band 1 of ASTER images showed the highest correlation coefficient with WQI (R^2 = 0.86) according to logarithmic regression analysis.

Keywords:Water Quality Index, ASTER, Egypt, Nile River, Rosetta River Nile branch

INTRODUCTION

Water is vital for life on the earth so that the pattern of human being residence throughoutthe history has often been dependent on availability of water resources. Unfortunately, the growth of human populations and their requests for more water of high quality for economic activities and domestic purposes poses a threat to this valuable resource(Ali et al., 2014). The expectations say; if the presenttrend of water use continues, the request for fresh water will rise by 56% more than what is currently available (UNEP, 2002).

The agreement signed between Egypt and Sudan in 1956 determines Egypt's share of Nile River water at 55.5 Billion Cubic Meters (BCM) every year. (Abdelkader, 2015). Egypt depends mainly on water from the Nile River due to the limited amount of rainfall, therefore the Nile River provides Egypt with more than 90% of its water needs. Only irrigation accounts for more than 90% of the total consumption (Wahaab&Badawy, 2004).

Water quality is defined as the state of the water resource related to the specific uses (Lal, 2011). Water quality index (WQI) is a remarkable classification to describe the general water quality status in simple words; such as excellent, good, bad, etc. to be easily understandable to the public (Khwakaramet al.,2015; Gangwar et al., 2013). It is one of the most vital tools to observe the pollution of surface and ground water and can be utilized effectively to achieve water quality upgrading programs (Alam and Pathak, 2010; Elsokkary and Abukila 2011).

Water quality has a compelling and huge significance in view of its immediate effect on the general health of human, ecological integrity, aquatic life and sustainable economic development (Ifabiyi, 2008). For example, the water transported illnesses are responsible for about 3 million deaths and thesickness of a billion person annually, on the global scales (World Bank, 1993).

Surface water quality became one of the most serious issues that the nations is confronting currently; especially due to the concern of freshwater scarceness in the future (Pesce&Wunderlin, 2000). Many investigations have been directed to address water quality at the global rivers such as Amazon River (Affonso et al., 2011), Xingu River (Rodrigues-Filho et al., 2015) and Ogun River (Adebayo et al., 2017).

WQI has been applied to the predicting water condition of Nile River for a different purpose in Egypt (Brown et al., 2003; El-Fadel et al., 2003; Radwan, 2005; El-Bouraie et al., 2011; Khan et al., 2011; Ezzat et al., 2012; El-Ayouti&Abou-Ali, 2013; Ali et al., 2014; ; Elewa, 2014; Abdelkader, 2015). They

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concluded that the deterioration of the River water quality occurs due to several factors such as urbanization, industrialization and agricultural wastes.

Water of the Nile River is facing a significant stress due to the highly overcrowding of the Egyptian population on the Nile Valley and Delta especially in branches of Damietta and Rosetta (Agrama&El-Sayed, 2013). The Egyptian population has a high growth increasing rate; it was 20 million in 1952 and 38 million in 1977 up to 90 million in recent days. Also, the rising of living standards has put more pressure on water resources; especially with the Nile River yield facing dramatic changes from year to another (Abdel-Shafy&Aly, 2002, Elsokkary, 2012).

Egypt has witnessed a great industrial revolution in recent years. This revolution has directed to a dramatic reduce in the Nile water quality (Abd-ElAal, 2006). In addition, there are numerous factors that affect the suitability of Nile River water, such as agricultural water drainage, which always carries pesticides and residues of fertilizers and domestic wastewater (Brown et al., 2003).

Remote sensing is using worldwide to atmospheric, aquatic, and terrestrial systems observation, so it allows use to obtain reliable data about water quality (Gürsoy et al., 2015). Remote sensing is more useful than the traditional monitoring techniques especially in large water bodies where it saves the time and effort (Tyler et al., 2006).

Many researchers have investigated the effectiveness of different satellite sensors for water quality monitoring. We found that the Thematic Mapper (TM) images are widely used for water quality studies (Al-Bahrani et al., 2012; Alparslan et al., 2010; Hadjimitsis&Clayton, 2011; Tahhery et al., 2015; Wang &Ma, 2001). Other researchers have assessed water quality using Enhanced Thematic Mapper Plus (ETM+) satellite data (Alparslan et al., 2007; Wen &Yang, 2011). The Moderate Resolution Imaging Spectroradiometer (MODIS) data (originally designed for land use) also has been used for the same purpose (Chen et al., 2007). The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data is a relatively new medium resolution image and did not used for monitoring the water quality and this is a novelty in this work.

Using aquatic environments for various uses requires sustainable maintenance and monitoring in order to ensure good water quality protection to current and future generations (Affonso et al., 2011), but the main challenge of this concept is the degradation of water quality by agricultural, domestic and industrial pollution (Dimian et al., 2014).This pollution causes many problems in Rosetta River Nile branch, as happened in summer 2012 whereas found many tons of fish dead on the water surface (Dimian et al., 2014). So, this research was initiated with the objective of evaluating the water quality for agricultural uses of Rosetta Nile River branch through the calculation of water quality index (WQI) and to investigate the feasibility of utilizing ASTER data to identify water quality for irrigation purposes.

MATERIALS AND METHODS

Study Area

El-Beheira Governorate presents aterritory of 9826 km^2, representing 1% of Egypt's total area, and Includes 15 Markaz, 15 cities, 84 rural local units, 497 villages and 5737 hamlets. As per the last results of the 2006 census, the total population reached to 4.74 million people; 19.2% of them live in urban areas (cities), and 80.8% are in the rural areas (villages), therefor it is considered as an agriculture governorate. (EGSA, 2007).

Nile River crosses Egypt from South to North, for around 950 km, beginning from the High Dam of Aswan to Delta barrage, at that point it splits into two branches (Rosetta and Damietta) forming between them the Delta region. Rosetta River Nile branch extends northwards for about 239 km on the western border of the Nile Delta and it represents the main freshwater stream on this side with an average width of 180 m and depth ranges from 2 to 4 m. It ends at Idfina Barrage which discharges excess water to the Mediterranean Sea after 30 km (Ezzat et al., 2012).

The study area is existed on the both sides of Rosetta River Nile branch. The Eastern side started from Kafr El-Zayat city (290775 E, 3411855 N) up to Mutubas(264060 E, 3465877 N) and the Western side started from Monshaat Amin Ismail village (290594 E, 3411856 N) up to Idfina(263699 E, 3465899N). The study area is extended about 65 km from the start point and until Idfina Barrage; as shown in Fig.(1).

Sampling and Analytical Methods.

Six sites were chosen to collect 18 water samples; covering about 65 km distance along the course of the Rosetta branch during April 2016. (Fig.1). The selected sampling sites were located on both sides of the Rosetta branch, in addition to a sample from the middle of the branch. The global positioning system (GPS) was used to identify the sampling locations. Names of sampling locations and their coordinates are displayed in Table 1. All water parameters were measured in laboratory of directorate of agriculture, Damanhour, El-Beheira governorate.

pH meter and Electrical Conductivity (EC) meter were used for determination of pH and EC, respectively.

Table 1. Coordinates of water samples and location names

Points	Side	Coordinates		Location
		E	N	
1	Western	290594	3411856	Monshaat Amin Ismail
	Middle	290698	3411856	Middle of Nile
	Eastern	290775	3411855	Kafr El-Zayat
2	Western	286438	3421065	Nikla Al-Inab
	Middle	286587	3420977	Middle of Nile
	Eastern	286726	3420902	Mahallat Al-Laban
3	Western	282389	3435166	Shubrakhit
	Middle	282495	3435107	Middle of Nile
	Eastern	282601	3435105	MahallatDiyay
4	Western	273959	3446864	Al-Rahmaniyyah
	Middle	274288	3446898	Middle of Nile
	Eastern	274591	3446970	Desouk
5	Western	265096	3452911	El-Mahmoudeya
	Middle	265110	3453316	Middle of Nile
	Eastern	265304	3453588	Fuwwah
6	Western	263699	3465899	Idfina
	Middle	263862	3465869	Middle of Nile
	Eastern	264060	3465877	Mutubas

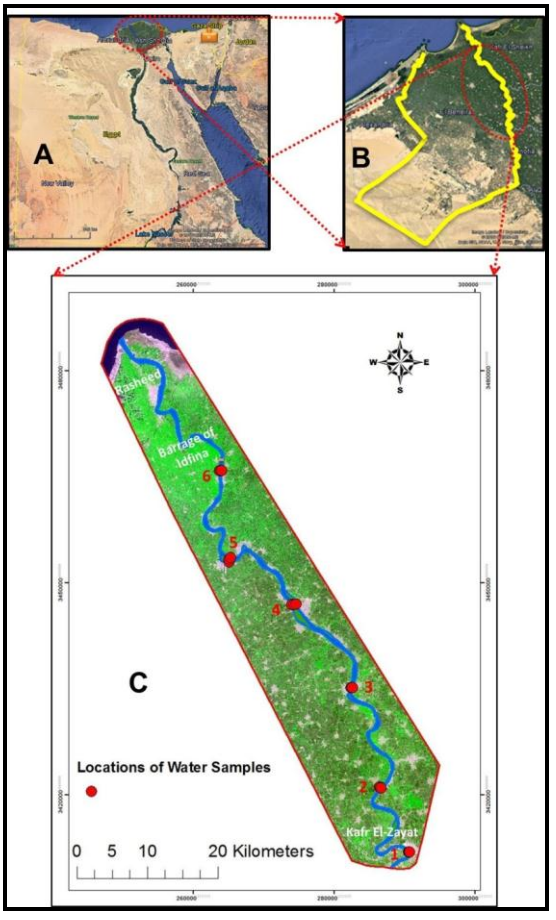

Figure 1. The study area; a: Egypt map, b: El-Beheira map and c: study area and locations of water samples (Aster Images)

The versenate titration method was used for determination of soluble calcium and magnesium ions. Sodiumand potassium ion concentrations were photometrically determined by the flame photometer. Bicarbonate was titrated by using methyl orange indicator and Mohr's method was applied to determine chloride concentration (Jackson, 1967).

The water quality parameters of Magnesium Content (MC), Sodium Percentage (SP), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Permeability Index (PI) were calculated by the following equations:

$\mathbf{MC}\ \% = (Mg^{2+}/(Mg^{2+} + Ca^{2+})) * 100$(Pitchaiah, 1995)
(1)

$\mathbf{SP} = ((Na^{+} + K^{+})/(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})) * 100$
(Pathani et al., 2002)(2)

$\mathbf{SAR} = Na^{+} / \sqrt{(Mg^{2+} + Ca^{2+})/2}$(Raghunath, 1987)(3)

$\mathbf{RSC} = (CO3^{-} + HCO3^{-}) - (Mg^{2+} + Ca^{2+})$
(Domenico and Schwartz, 1990)(4)

$\mathrm{PI} = ((Na^{+} + HCO3^{-})/(Ca^{2+} + Mg^{2+} + Na^{+})) * 100$
(Domenico and Schwartz, 1990) (5)

(Concentrations are in meq.L^{-1})

WQI Calculation

In this study, WQI calculation was depended on eight (8) essential chemical and physical water parameters by utilizing the recommended standards of irrigation water quality according to (FAO) rules (Ayers &Westcot, 1985).

To calculate the WQI, the weighted arithmetic Index strategy was utilized (Cude, 2001). In this method, the diverse water quality parameters were multiplied by a weighting factor and after that aggregated utilizing simple arithmetic mean. For doing the computation of WQI according this method:

Firstly: the quality rating scale (Qi) for every characteristic was computed by using equation (6):

(6)$\mathbf{Qi} = [Ci/Si] * 100$

Qi for the pH characteristic has a specific condition and was computed based on equation(7):

$\mathbf{Qi} = [Ci - Vi/Si - Vi] * 100$(7)
where,

Qi =Quality rating of (i)th characteristic for an aggregate of (n) water quality characteristics.
Ci =The value of water quality characteristic estimated in the laboratory.
Si =The value of water quality characteristic in accordance with FAO recommendation.

Vi = The ideal (perfect) value, for instance 7 for pH.

Secondly:the relative weight was computed by a value inversely proportional to FAO standard recommendation for the specific characteristic utilizing the next formula;
$\mathbf{Wi} = 1/Si$(8)
whereas,

Wi = Relative weight for nth characteristic.
Si = The value of water quality characteristic in accordance with FAO recommendation.
1 is Proportionality constant.

Finally, the general WQI was computed by the quality rating and the relative weight according to the equation (9):
$\mathbf{QWI} = \sum \mathbf{QiWi} / \sum \mathbf{wi}$(9)
The status of water quality according to WQIas shown in Table 2 (Vasanthavigar et al., 2010)

Table 2. The ranks of water quality according to WQI

Water Quality Index levels	Rating
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor (bad)
>300	Unsuitable (unfit)

Remote Sensing Data (ASTER)

In this study two ASTER images (Figure 2) were downloaded from (https://earthexplorer.usgs.gov/) after that, they were merged to be one mosaic image, and then it clipped according to the specific study area (Figure 1). ASTER Visible and Near-Infrared (VNIR) spectral bands for 22nd May, 2016 was used (band 1 (green): 0.52 - 0.60 µm, band 2 (red): 0.63 - 0.69 µm, and band 3 (near infrared): 0.76 - 0.86 µm) with spatial resolution 15 m. ENvironment for Visualizing Images software (ENVI5.3) was used to extract the digital numbers (DNs) at ASTER VNIR bands for each water samples locations along the study area.

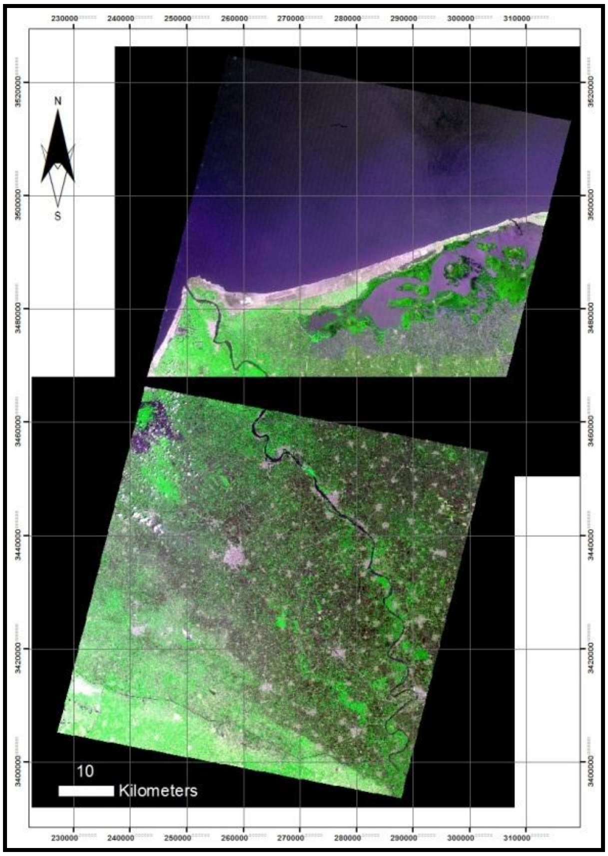

Figure 2. ASTER images of the study area (G: Band 1, R: Band 2 and NIR: Band 3)

RESULTS AND DISCUSSION

Chemical Analysis

The suitability of water for irrigation usages depends on the impacts of the water minerals on all of the plants and the soil. The critical hydrochemical characteristics used to evaluate water suitability for irrigation usage are: pH, EC, SP, SAR, RSC, PI, and MC (Aref&Roosta, 2016).

pH is a vital factor used to determine the suitability of water for different uses (Ahipathy&Puttaiah, 2006). The values of pH ranged from 6.00 to 8.10 (Table 3), indicating that the water samples are almost neutral and there is a relative match with ideal pH values of surface water, which are in the scope 6.5 to 8.5 (Ayers &Westcot, 1985).

The results showed that EC values (0.41-0.53 $dS.m^{-1}$) were lower than the allowable level recommended by the FAO for irrigation water (Table 3, 4 and Figure 3), except the point one (Kafr El-Zayat) whose results (0.74-0.78 $dS.m^{-1}$) were higher than the permissible level due to the industrial wastewater received by the Rosetta River Nile branch from Maleya and salt and soda factories at this location(Donia2005; El-Gammal&El-Shazely, 2008).

The determination of sodium concentration is necessary to consider the water suitability for irrigation usage; because high sodium concentration can decrease soil permeability and destroys soil structure and it is a measure of alkali/sodium hazard on crops as well (Krishna et al., 2009). If utilizing water that has a high concentration of soluble salts to irrigate soil leads to the emergence of salty soil, the high sodium concentration leads to the emergence of an alkaline soil.Usual sodium concentration ranges in irrigation water between 0-40 $meq.L^{-1}$(Ayers &Westcot, 1985), thus all water samples was found to contain a sodium concentration lower than the permissible level (2.29-3.97 $meq.L^{-1}$) (Table 3).

SP is considered as the percentage of sodium and potassium against all cations concentration and used for judging the quality of irrigation water. Use of water, which has highly sodium percentage for irrigation, impedes the plant growth due to the sodium reaction with the soil and the reduction in its permeability (Todd, 1980).

The SP values of the study area were 14.41% to 47.69%, thus the water samples were classified to excellent, good and permissible for irrigation, according to this parameter (Table 4 and Figure 3). It is recommended to add gypsum to the soil to decrease the impact of the high level of sodium on irrigation water.

In this study SAR was found to be 0.9 to 2.5$meq.L^{-1}$(Figure 3). The low value of SAR in water of the study area can be classified as a matter of excellent category (Table 4) and it can be utilized for irrigation in almost all soil types.

FAO has recommended the guideline level of potassium at 0.5$meq.L^{-1}$in irrigation water (Ayers &Westcot, 1985). According to FAO standard criteria, whole samples fall within the guideline level (Table 3 and 4).

The rocks are considered one of the main sources of Calcium in the water. FAO has prescribed the guideline level of calcium at (0-20 $meq.L^{-1}$) in irrigation water (Ayers &Westcot, 1985). The ranges of Ca^{+2} in water samples are 0.44 to 3.60 $meq.L^{-1}$as displayed in Table (3). All samples were lower than the acceptable level.

MC of water is one of the most significant factors which determine the water quality for irrigation usages, whereas more magnesium in irrigation water; means the soils to become more alkaline and accordingly will adversely affect crop production (Joshi et al., 2009). MC in the many studies is identified as a magnesium

Table 3. Laboratory analysis of the studied Nile water samples

Points	Side	pH	EC dS.m-1	Na^+	K^+	Ca^{++}	Mg^{++}	$HCO3^-$	Cl^-
				meq.L^{-1}					
	Western	7.10	0.78	3.53	0.14	2.44	2.08	2.85	2.60
1	**Middle**	7.30	0.78	3.60	0.13	2.02	2.52	2.95	2.50
	Eastern	7.20	0.74	3.68	0.13	2.52	2.28	2.74	2.60
	Western	6.10	0.46	3.97	0.18	2.54	2.52	2.74	2.90
2	**Middle**	6.80	0.48	3.83	0.21	2.64	3.80	3.25	2.80
	Eastern	7.10	0.46	3.76	0.20	3.60	14.30	3.05	3.10
	Western	7.00	0.44	3.47	0.14	1.10	2.86	2.74	2.40
3	**Middle**	6.80	0.42	3.47	0.14	1.22	3.40	2.64	2.40
	Eastern	6.00	0.41	3.47	0.13	0.44	3.64	2.64	2.60
	Western	7.00	0.52	2.81	0.08	2.04	1.30	3.56	3.40
4	**Middle**	7.20	0.53	2.51	0.08	3.04	1.46	2.64	2.80
	Eastern	8.00	0.53	2.59	0.08	2.54	1.54	2.95	3.10
	Western	7.30	0.47	2.29	0.08	2.76	1.38	2.34	2.90
5	**Middle**	7.30	0.48	2.51	0.08	2.96	1.02	4.27	3.70
	Eastern	7.30	0.46	2.29	0.08	2.34	2.04	3.15	3.10
	Western	7.20	0.45	2.51	0.14	3.20	3.20	2.95	2.70
6	**Middle**	7.10	0.46	2.29	0.16	2.40	3.90	2.44	2.80
	Eastern	7.40	0.45	2.51	0.13	2.60	13.10	3.15	2.80

Table 4. Chemical parameters and water classification for irrigation purposes according to FAO guidelines in the study area

Parameter	Parameter Value	Water Class	References	Sample No.
(EC)	<0.25	Excellent	(Richards, 1954)	Nil
dS/m	0.25–0.75	Good	(Raghunath, 1987)	2, 3, 4, 5, 6
	0.75–2	Permissible		1
	2–3	Doubtful		Nil
	>3	Unsuitable		Nil
(SP)	0–20	Excellent	(Wilcox, 1955)	2 Eastern, 6 Eastern
%	20–40	Good		2 Middle, 4 Eastern, 4 Middle, 5, 6 Western, 6 Middle
	40–60	Permissible		1, 2 Western, 3, 4 Western
	60–80	Doubtful		Nil
	>80	Unsuitable		Nil
(SAR)	<10	Excellent	(Todd, 1980)	1, 2, 3, 4, 5, 6
meq.L^{-1}	10–18	Good	(Richards, 1954)	Nil
	19–26	Doubtful	(Saleh et al., 1999)	Nil
	>26	Unsuitable		Nil
	<50	Suitable	(Raghunath, 1987)	1 Eastern, 1 Western, 2 Western, 4, 5
(MC)				1 Middle, 2 Eastern, 2 Middle, 3, 6
%	>50	Unsuitable		
(RSC)	<1.25	Good	(Eaton, 1950)	1, 2, 3, 4, 5, 6
meq.L^{-1}	1.25–2.5	Doubtful	(Richards, 1954)	Nil
	>2.5	Unsuitable	(Raghunath, 1987)	Nil
(PI)	>75	Excellent	(Doneen, 1964)	1, 3, 4 Eastern, 4 Western, 5 Eastern,
%			(Raghunath, 1987)	5 Middle
	75 – 25	Good		2, 4 Middle, 5 Western, 6
	<25	Unsuitable		Nil

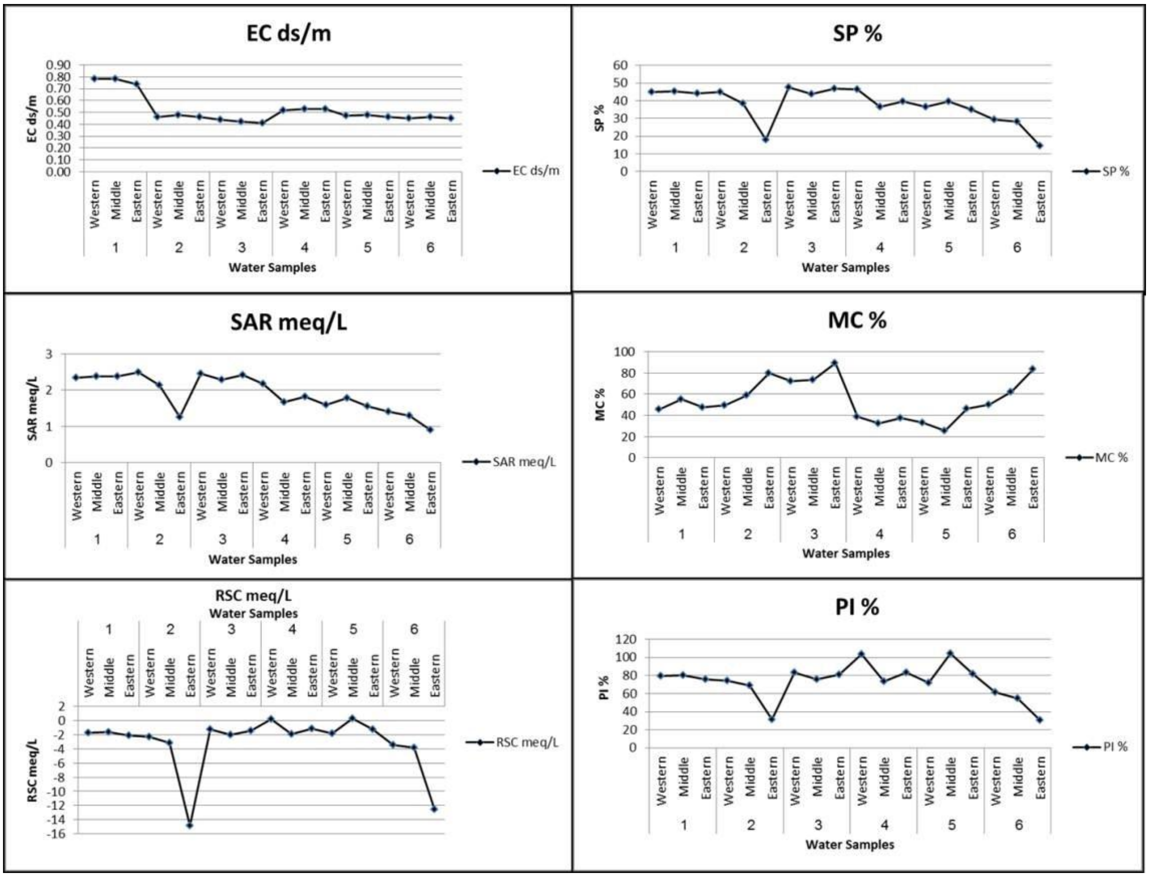

Figure 3. Chemical characteristics of the studied Nile water samples

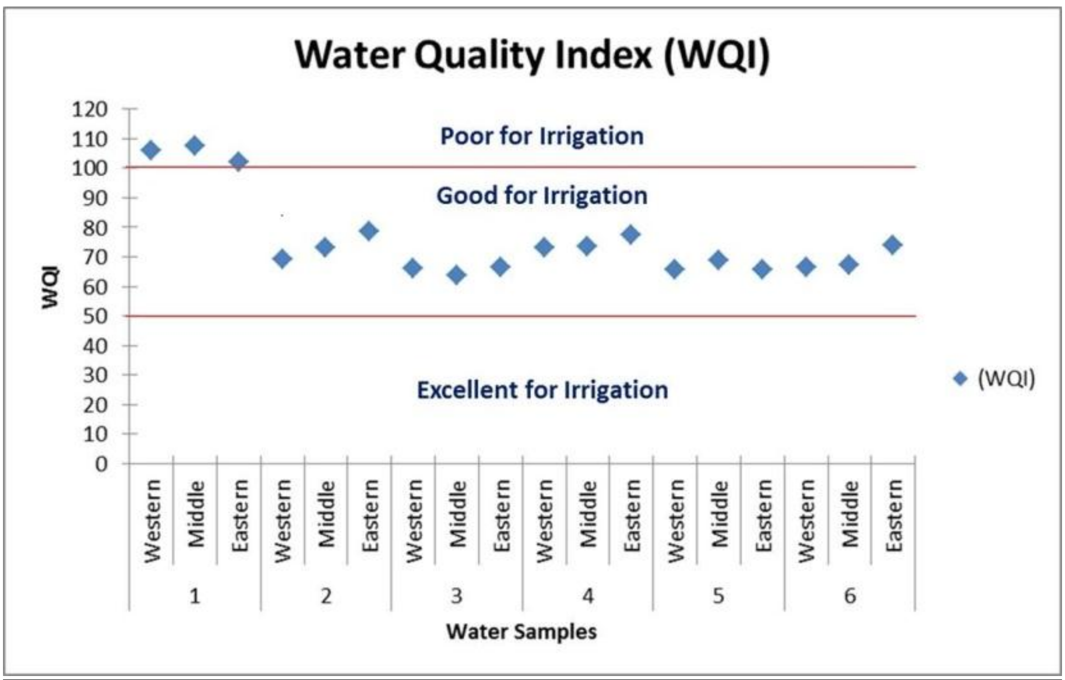

Figure 4. Water Quality Index values for all water samples

ratio (MR), and magnesium adsorption ratio (MAR) and magnesium hazard (MH). The water is categorized as unsuitable for irrigation use if the values of magnesium content exceeds 50 (Aref&Roosta, 2016).

As per FAO criteria the guideline level of magnesium in irrigation water is (0-5 meq.L^{-1}) (Ayers &Westcot 1985).The magnesium concentration values were in the range between 1.02 and 14.30meq.L^{-1}(Table 3). All samples have various values of magnesium. Magnesium may reach to the water by many various ways (Deshpande&Aher, 2012) such as chemical industries, fertilizer application and cattle feed. In the present investigation, the magnesium content of the water of the study area varies from 25.63% to 89.22% (Figure 3). So, water is classified between suitable and unsuitable for irrigation purposes according to magnesium content (Table 4).

The values of bicarbonate in this investigation were in the range between 2.34 and 4.27meq.L^{-1}as presented in Table 3. Accordingly, all the studied samples were higher than the permissible level according to FAO (0-10 meq.L^{-1}) (Ayers &Westcot, 1985).

The concentration of carbonate and bicarbonate also affects irrigation water suitability. There is a hypothesis which assumed that all calcium and magnesium ions would precipitate as carbonates, consequently Eaton proposed the concept of RSC (Eaton, 1950) Which is still utilized to evaluate the quality of water for irrigation (Shafiek et al., 2015). The water with high RSC has a high pH and using such water in irrigation will cause the soil to degrade due to the deposition of sodium carbonate.

Water with RSC values over 2.5 is generally not suitable for irrigation uses, from 1.25 to 2.5 meq.$L^{-1}$is considered marginal and with less than 1.25 is safe (Eaton, 1950; Richards, 1954; Raghunath, 1987). In this study RSC values were below1.25 meq.L^{-1}in all samples (Figure 3).So, water of the study area could be considered suitable for irrigation purposes, according to RSC values (Table 4).

Sodium, calcium, magnesium and bicarbonate content of irrigation water affects the soil permeability.So, we consider it as an important factor for suitability of irrigation. A rule of evaluating the water suitability for irrigation was based on its PI. The PI in Class I and Class II started from 75% or more and it was categorized as "excellent"for irrigation, whereas Class III was unsuitable with 25% or less (Doneen, 1964; Raghunath, 1987).

In the current study the lowest value of PI is 31.10 % and the highest value is 104.45 % (Figure 3). Hence,water in the investigation area is classified between excellent and good for irrigation purposes according to PI values (Table 4).

Chloride is a commonly ion in irrigation waters. It has toxic effects on the plant that are immediately seen as leaf burns or leaf tissue deaths. The chloride content was found between 2.4 and 3.7 meq.L^{-1}as shown in Table 3, therefore it lies within the permissible limits (0-30meq.L^{-1}), according to FAO guidelines (Ayers &Westcot, 1985).

Water Quality Index (WQI)

As per the estimated values WQI of the studied locations, there was a poor water quality for irrigation purposes,in accordance with FAO guidelines, at location 1(WQI values between 100-200) at Kafr El-Zayat.At this location Rosetta branch receives wastewater from Maleya and Salt and Soda companies (Donia 2005; El-Gammal & El-Shazely, 2008). Along the down stream from this site WQI values were decreasing (the water quality be better) with distanceby the natural self-purification (Figure 4). This operation is defined as the capacity of flowing water to disinfect themselves from sewage or other wastes naturally(Khwakaram et al., 2015) (Figure 4). Table 5 shows an example for the calculation of WQI for the water samples.

Correlation Coefficient Analysis

The correlation coefficient is a usually utilized measurement to prove the relation between two variables. It is used to measure the proximity of the relation between variables. If it is closer to +1 or –1, it means that there is a strong linear relation between variables. It is simply a measure to show how well one variable predicts another (Al-hadithi, 2012). The correlation coefficient analysis in the current study showed that the EC differences are mainly occurring by Sodium (r=0.3) and calcium (r = 0.1) concentration. The correlation coefficient between WQI and water quality characteristics was prepared and it illustrates that electrical conductivity and sodium were the most affecting factors (r=1.0 and r=0.4, respectively) for the calculated WQI values of the studied water samples (Table 6) where a very high correlation coefficient between WQI and those factors was found.

ASTER Data and Water Quality Index

Table 7 shows the WQI and digital numbers (DNs)values in VNIR bands (1, 2, and 3) of ASTER images for the eighteen water samples locations of the Rosetta branch. Regression analysis between the DNs in the VNIR bands for ASTER satellite images and the

Table 5. A case for figuring of WQI for the water samples (number 1 western)

Point	Characteristics	Ci	Si	Wi	Qi	QiWi
	pH	7.10	8.5	0.118	6.667	0.784
	EC	0.78	0.7	1.429	111.429	159.184
	Na	81.19	25	0.040	324.760	12.990
	K	5.46	20	0.050	27.300	1.365
1	Ca	48.80	75	0.013	65.067	0.868
western	Mg	24.96	30	0.033	83.200	2.773
	HCO3	173.60	92	0.011	188.696	2.051
	Cl	92.30	142	0.007	65.000	0.458
	∑			1.701		180.473
	WQI	**∑QiWi/∑Wi = 106.11**				

Table 6. The correlation coefficient between WQI and water quality characteristics in the study area

Parameters	EC	Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	MC	SP	SAR	RSC	PI	WQI
EC	1.0												
Na^+	**0.3**	1.0											
K^+	-0.1	0.7	1.0										
Ca^{2+}	**0.1**	-0.3	0.0	1.0									
Mg^{2+}	-0.2	0.2	0.5	0.3	1.0								
HCO_3^-	0.0	-0.1	-0.2	0.3	0.0	1.0							
Cl^-	-0.2	-0.4	-0.4	0.5	0.0	0.7	1.0						
MC	-0.3	0.4	0.6	-0.5	0.7	-0.3	-0.5	1.0					
SP	0.3	0.4	-0.2	-0.6	-0.8	0.0	-0.2	-0.3	1.0				
SAR	0.4	0.7	0.1	-0.6	-0.6	-0.1	-0.4	0.0	0.9	1.0			
RSC	0.2	-0.1	-0.5	-0.4	-1.0	0.0	0.0	-0.6	0.9	0.6	1.0		
PI	0.2	0.0	-0.5	-0.4	-0.9	0.3	0.3	-0.6	0.8	0.6	0.9	1.0	
WQI	**1.0**	**0.4**	0.1	0.1	0.0	0.0	-0.2	-0.1	0.2	**0.3**	0.0	0.0	1.0

Table 7. Digital numbers of ASTER VNIR bands for water samples locations and WQI

Points	Side	E	N	(WQI)	Band1 (0.52 - 0.60)	Band2 (0.63 - 0.69)	Band3 (0.76 - 0.86)
		UTM (Zone 36N)			µm		
	Western	290594	3411856	106.11	161	174	169
1	Middle	290698	3411856	107.42	163	168	169
	Eastern	290775	3411855	102.17	158	170	166
	Western	286438	3421065	69.26	154	167	164
2	Middle	286587	3420977	73.20	155	167	164
	Eastern	286726	3420902	78.52	157	170	164
	Western	282389	3435166	65.91	153	165	162
3	Middle	282495	3435107	63.92	150	162	160
	Eastern	282601	3435105	66.40	154	168	162
	Western	273959	3446864	73.15	153	164	164
4	Middle	274288	3446898	73.58	154	160	161
	Eastern	274591	3446970	77.56	157	167	167
	Western	265096	3452911	65.68	153	159	162
5	Middle	265110	3453316	68.94	154	157	164
	Eastern	265304	3453588	65.73	153	160	163
	Western	263699	3465899	66.33	153	167	163
6	Middle	263862	3465869	67.34	154	167	162
	Eastern	264060	3465877	74.00	155	168	164

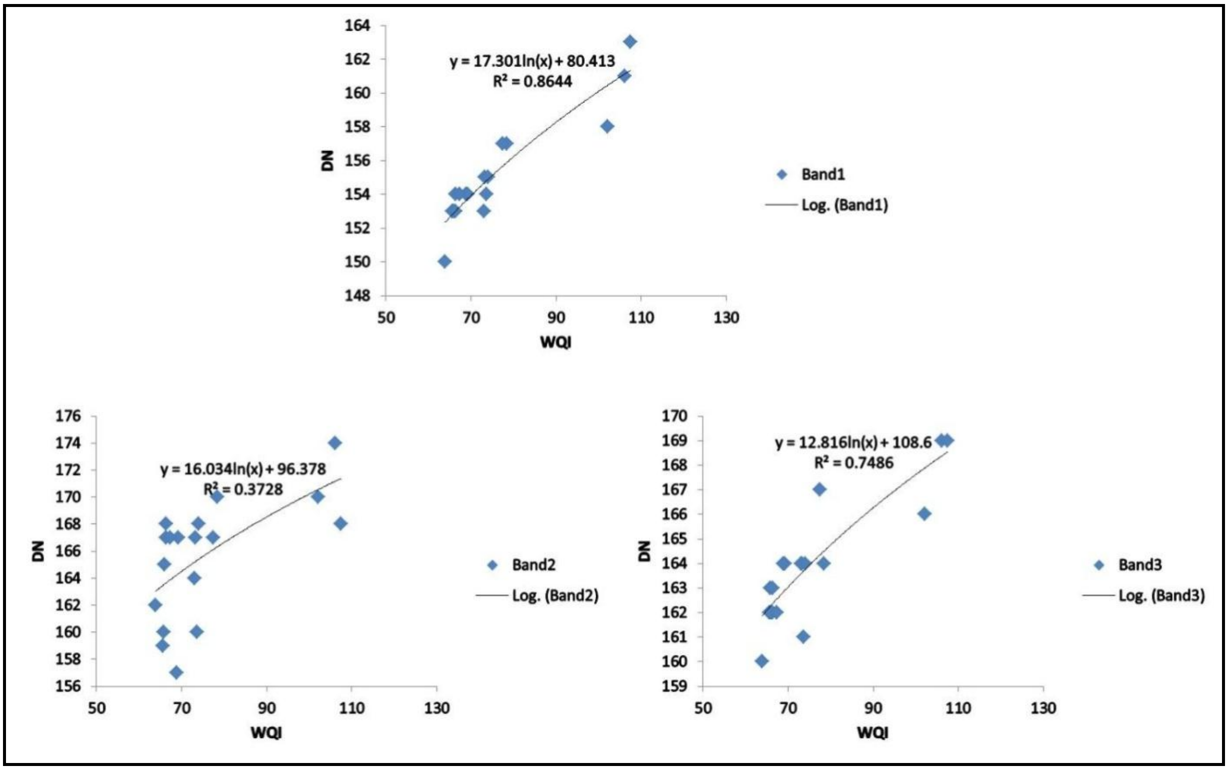

Figure 5. The logarithmic regression analysis between WQI and DNs of ASTER VINR bands

water quality index for the water samples were computed. It was noticed that the logarithmic regression analysis gave highest correlation coefficient between the band 1 of the ASTER images and the water quality index (R^2 = 0.86). The digital numbers of band 2 in ASTER images could be used in the logarithmic equation to find WQI (Figure 5).

CONCLUSION

Egypt is poor in water resources, with the quick increment in the inhabitants number and the need to meet the expanding requests for agricultural water use (irrigation and livestock drinking purposes), domestic use and industrial consumption; consequently all of those factors lead to a depletion of available water resources and a reduction of water quality. Industrial wastewater from Maleya and salt and soda factories in the city of kafr el zayat is the significant source of the water pollution in the study area. The self-purification has been observed in Rosetta River Nile branch in the study area and it has contributed to the gradual improvement before Idfina Barrage. Evaluation of Nile water quality for irrigation in the study area was executed using various parameters (SP, SAR, RSC, PI, MC and EC). Most of the water samples fall under excellent, good and Permissible limitations, according to the parameters values. Therefore, the results concluded that the Nile water quality of the Rosetta River Nile branch was in general suitable for irrigation. As per WQI, the majority of samples were good for irrigation except sample one (1) which was poor. The electrical conductivity and sodium were the most affecting characteristics for the calculated WQI values of the study area. In order to improve the water quality in the Nile River, it would be essential to stop the Industrial waste and sewage discharging from reaching the river and this could be by expanding the construction of treatment plants. Also the regular monitoring of water quality is very significant to detect the pollution fluxes and reduce their environmental effects and the results showed that the use of digital numbers of band 1 from ASTER images help to achieve this task.

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الملخص العربي

رصد جودة المياه للأغراض الزراعية باستخدام صور عالية الدقة (ASTER): دراسة حالة من مصر

عماد فوزى عبد العاطى

ترتبط حياة مصر ارتباطًا كبيرًا بنهر النيل حيث يعتبر هو المصدر الرئيسي للمياه في مصر والذي يستخدم لأغراض مثل الزراعة والشرب وتوليد الكهرباء والصناعة. يُعد مؤشر جودة المياه (WQI) أداة قيّمة وبسيطة لتوضيح وشرح البيانات الهائلة التي يتم الحصول عليها من أي جسم مائي. يمكن أن يكون الاستشعار عن بعد أداة مفيدة في مراقبة جودة المياه. في هذا البحث تم تطبيق مؤشر جودة المياه لتقييم ملاءمة مياه النيل لاستخدام الري ، في فرع رشيد، محافظة البحيرة ، مصر. استخدم تحليل الانحدار للتحقق من الارتباط بين (WQI)وبيانات الاستشعار عن بعد (ASTER). تم جمع عينات المياه من ستة مواقع مختلفة ، على امتداد ٦٥ كم على طول فرع رشيد على مسافات متساوية تقريبا بدءا من مدينة كفر الزيات إلى قناطر إدفينا. استخدمت الزجاجات البلاستيكية المصنوعة من البولي إيثيلين (سعة ١ لتر) لجمع عينات المياه. تم تقييم العينات لثمانية (٨) معايير كيميائية ، وهي درجة الحموضة ، التوصيل الكهربائي، الصوديوم ، البوتاسيوم، الكالسيوم ، المغنيسيوم، البيكربونات والكلوريدات. أوضحت النتائج أن مؤشر جودة المياه كان جيداً في الغالب لأغراض الري وفقاً لدليل منظمة الزراعة والاغذية (قيم WQI بين ٥٠-١٠٠) ، باستثناء الموقع الأول الذي كانت المياه عنده غير صالحة للري (قيم WQI بين ١٠٠-٢٠٠) بسبب التلوث الاصطناعي في هذا الموقع. التوصيل الكهربي وتركيز الصوديوم كانا أهم الخصائص التي تؤثر على مؤشر نوعية المياه المحسوب في منطقة الدراسة ، كذلك أظهر النطاق ١ من صور الاقمار الصناعية (ASTER) أعلى معامل ارتباط مع مؤشر جودة المياه ($R2 = 0.86$) وفقًا لتحليل الانحدار اللوغاريتمي.