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Original Article

Anthropogenic Impacts on Water Quality of River Nile and Marine Environment, Rosetta Branch Using Geospatial Analyses

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Abstract

Present research focused on studying water quality of three ecosystems in Rosetta branch; fresh River Nile, estuary and Sea water based on Landsat data and samples analyses. Two multispectral Landsat images dated 26th of February 2017 and 1st of March 2018 provided the necessary spectral data to this research. Nineteen surface water samples were collected on 18th March 2017 and investigated for pH, EC, silicate, phosphate, nitrite, nitrate, organic matter (OM) content and Nitrogen/Phosphorus ratio. The calibrated Landsat data, synchronized with the field trip, was processed to produce Land use cover map (LULC), Vegetation (NDVI), built-up (NDBI) and salinity indices (NDSI) to highlight the human activities in the adjacent areas. Statistical analyses were carried out to correlate the existed land uses in 2017 with water quality characteristics and to monitor spectral reflectance change in 2018 responding to water quality change. NDVI showed positive correlations with nitrate (0.416), nitrite (0.517), silicate (0.272) and N/P ratio (0.345) which confirmed the impact of agricultural activities on water nutrients. Although urban areas occupied 4.87 %, they contributed to water OM levels (R= 0.488). Means of nitrite, nitrate, phosphate and N/P followed the order; Estuary > River > Sea however for OM and EC, they followed the order; Sea > Estuary > River. N/P ratio ranged from 12.91 to 31.52 which indicated that phosphorus is the limiting factor for bio-growth of algae in the three studied environments. In this study, innovative model for calculating water phosphate was developed in 2017 which indicated a similar fluctuation in phosphate levels in 2018 within different locations. It can be concluded that remote sensing facilitates the spatial identification of the potential sources of water pollution and helps in the qualitative assessment of nutrients and organic pollutant levels in water resources.

1. Introduction

Urbanization, overpopulation and industrialization increase the stress on water resources. Further, discharges from untreated sewage water cause severe water quality problems either for fresh or marine environments (El-Gammal and El-Shazely, 2008). River Nile, which is the main source of drinking water in Egypt, receives heavy load of domestic, agricultural and industrial wastes from multiple sources. It is divided into two branches namely; Damietta and Rosetta. In Rosetta Branch of the River Nile, El-Bouraie *et al.* (2010) identified pollution from different origins; domestic, sewage, industrial and agricultural. Rosetta branch is influenced by several industrial companies (e.g. Kafr El-Zayat City) which potentially impact and deteriorate the quality of water (Donia *et al.*, 2003; Elhaddad and Al-Zyoud, 2017). High River discharge could have resulted in silt and nutrients loading into the estuary affecting the sea water quality, which leads to a highly turbid water column (Jayachandran *et al.*, 2012).

Approximately 65 % of the Egyptian populations are connected to drinking water supply and only 24 % to sewage networks. Due to works under construction, the domestic wastewater network is expected to grow rapidly (Abdel-Wahaab and Badawy, 2004). Agriculture represents the major non-point source of pollution, with a number of possible impacts on the environment and human health. In many agricultural areas, contamination of surface and groundwater has originated from nitrates leaching from fertilizers, and bacteria from feed wastes and livestock. Agricultural wastes are considered as a potential diffuse source of water contamination. In Egypt, the major impacts of agriculture on water quality includes: (1) salinity changes, (2) quality deterioration owing to fertilizers and pesticides and (iii)

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probable eutrophication of water bodies owing to an increase in nutrient levels from fertilization (Drainage Research Institute, 1995).

Since the construction of the High Aswan Dam, the water quality of the River Nile is primarily dependent on the ecosystem characteristics and quality of Nasser Lake reservoir and secondary dependent on the water characteristics of the upper reaches of the Nile River. Water that is released from Nasser Lake generally shows the same global characters and the same temporal variation from every year. Downstream fluctuations in river water quality are primarily due to (1) the hydrodynamic regime of the river, (2) agricultural return flows, and (3) domestic and industrial wastewater discharges including oil wastes from boats. These changes are more obvious as the river flows through the densely urban and industrial centers of great Cairo and the Nile Delta region (El-Gohary and Abdel Wahaab, 1992).

On the other hand, the directly or indirectly introduction of substances into the marine environment, including estuaries, results in harmful effects which is known as marine pollution. This pollution causes toxic effects to the living resources and marine life, risk to human health, limitation in marine activities (e.g. fishing) and deterioration of water quality. The pollution of marine environment can be caused from land-based sources e.g. untreated sewage and the dumping of wastes which reach the sea and oceans through rivers and streams, fumes from power plants and factories, etc. (Elhaddad and Al-Zyoud, 2017).

Remote sensing and GIS have been universally used in studies of water quality (e.g. Senay *et al.,* 2001; El-Zeiny and El-Kafrawy, 2017). Boutiba and Bouakline (2011) stated that remote sensing provides spatial and temporal information that is not readily available from field investigations, thus making it possible to monitor the landscape changes effectively, identifying and evaluating water quality and problems. Many studies focused on the significant impact of land use on water pollution. Generally, built-up and agricultural lands have significant positive correlation with water pollution, which are received from point and non-point sources. Relationship between spectral data and water quality has been widely utilized in spatiotemporal and regional assessment of water pollution (El-Zeiny and El-Kafrawy, 2017). Land use is an important factor in defining the main land features and activities which might contribute to water pollution. Residential, agricultural and industrial activities are considered anthropogenic sources of pollution since pollutants are generated where people live and work (Huang *et al.,* 2015). Further, remote Sensing and GIS are widely used for investigation of eutrophication state (El-Amier *et al.,* 2016).

The main objective of this work is to observe and assess water quality along Rosetta branch considering fresh and saline environments, and relationships with present land uses by integrating remote sensing technology with field observations and sampling analyses.

1. Materials and Methods

2.1. Study area and sampling

The study area represents Rosetta branch of the River Nile which is located in three different governorates; Kafr El-Sheikh, El-Beheira and El-Gharbia (Figure 1). The area is extended from Latitude 30º 60´ N to 31º 20´ N and from Longitude 30º 15´ E to 30º 60´ E. Three different ecosystems were investigated; Mediterranean Sea (North), estuary and Fresh River Nile. In this area, the Mediterranean Sea has a great impact on the River Nile's water quality. The climatic condition of the area is typical Mediterranean environment with moderate temperature most of the year. The common wind direction is practically north-west direction most of the year that generates an overall eastward-flowing longshore current (El-Asmar and Hereher, 2010).

A total of 19 geo-referenced surface water samples were collected on 18^{th} of March 2017 (Table 1). Four samples were collected from Mediterranean Sea, three from the estuary and twelve from the fresh River Nile. The collected samples were transferred into the laboratory for further analyses.

Seven different water quality parameters were investigated including electric conductivity (EC), pH, nitrite, nitrate, silicate, phosphate and organic matter (OM). Conductivity was measured using conductivity meter (Thermo Electron Corporation, S/N 088341 USA) and the results were expressed as µm/cm. The collected samples were filtered using 0.45 µm membrane filters. In the filtered water samples, dissolved inorganic nitrogen forms (NO_2 and NO_3), dissolved inorganic phosphorus (PO_4) and silicate (SiO_4) were determined as described by Grasshoff *et al.* (1999). The developed colors of the nutrient salts were measured using spectrophotometer and all concentrations were expressed as µg/l. Organic matter (OM) was analyzed following the permanganate oxidation method (FAO, 1975).

2.2. Remotely sensed data acquisition and analyses

Free downloaded multispectral Landsat OLI images dated 26^{th} February 2017 and 1^{st} March 2018, path 177/ raw 38 were used in this study. Preprocessing procedures, including radiometric calibration and atmospheric correction, were firstly applied for calibration purposes. The calibrated images were, then, cropped to resize the area of study for further processing.

2.2.1. Supervised Classification

Maximum Likelihood Classification (MLC) has been widely used for supervised classification of satellite images to produce land use and land cover map (Chan *et al*., 2001). Field validation points were used to assess accuracy of the classification. These points were determined in the classified images and verified in the field using a GPS and the original false color images. This assessment shows the degree to which the derived image classification matches with reality (Campbell, 1996). In the present study, land use/cover map was used to identify the spatial distribution of land use which helped to define the probable sources of water pollution; i.e. urban and agriculture (El-Zeiny and El-Kafrawy, 2017). In the present study, the overall accuracy obtained for the classified image was 98.33% .

2.2.2. Spectral Retrieved Indices

The calibrated Landsat image was processed to produce three spectral indices based on the empirical equations in ENVI 5.1 following Zha *et al.* (2003). These indices are used to quantify land uses around the sampled sites and to facilitate the statistical relationships between water quality and spectral indices.

A. Normalized Difference Built-Up Index (NDBI) highlights urban areas.

$$NDBI= (SWIR-NIR) / (SWIR+NIR)$$

B. Normalized Difference Vegetation Index (NDVI) is a measure of density of vegetation.

$$NDVI= (NIR-Red) / (NIR+Red)$$

C. Normalized Differential Salinity Index (NDSI) is an indicator of land affected by salinization; it is just the reverse of the NDVI.

$$NDSI= (Red-NIR) / (Red+NIR)$$

2.3. Statistical analysis

Pearson's correlation was used to investigate the relationships between each pairs of the studied variables by using the SPSS software package (SPSS. ver.16). One-way ANOVA and mean values for the measured variables were separated on basis of Duncan's test at 0.1 probability level, using COSTAT 6.3 program. Cluster analyses based on Bray–Curtis similarity index were conducted using the PAST program (multivariate statistical package, ver. 1.72). Further, correlation coefficient was used to identify the relationship between land uses expressed in spectral indices and water quality parameters.

The satellite image acquired on 1st of March 2018 was calibrated to obtain a reflectance data to be integrated with 2017 image to assess the temporal changes in the spectral values as a result of water quality changes. This was achieved by obtaining the corresponding reflectance values at the sampling sites in 2017 and 2018. For this purpose, seven multispectral bands were utilized; B1 (0.4430 µm), B2 (0.4526 µm), B3 (0.5613 µm), B4 (0.6546 µm), B5 (0.8646 µm), B6 (1.6090 µm) and B7 (2.2010 µm). Regression analyses were employed for empirical equation generation using Excel software 2017.

2. Results and Discussions

3.1. Land use/ cover map (LULC)

There is a significant effect of land use on water quality; sites where agricultural, industrial and urban activities are practiced are considered anthropogenic sources of water pollution. Pollutants are generated where people live and work, therefore the spatial identification of various land uses is necessary for assessing the probable sources of water pollution. The MLC was used to create seven different LULC classes; agriculture, bare land, built-up, sabkha, water, water logging and wetland (Figure 2). The agricultural land dominated the whole study area (1393.63 km^2, 76.59 %); which might have an impact on water quality of the River Nile through the uncontrolled applications of chemical fertilizers. Saline and freshwater resources, including Mediterranean Sea and River Nile, were classified as "water" which represents the second dominant class in LULC map (204.26 km^2, 11.23 %). The third class was "built-up" areas (88.59 km^2, 4.87 %) which are distributed in several separate parts in the whole study area and are considered as a significant source of water pollution through the wastewater discharge into water bodies. In the northern parts, close to the Mediterranean Sea, three classes were mapped; Sabkha, water logging and wetlands recording 2.02 km^2 (0.11%), 7.31 km^2 (0.40 %) and 6.82 km^2 (0.37 %), respectively. The influence of Sea water intrusion and higher water table levels are the main factors inducing the formation of these classes.

3.2. Water Quality

The investigated sites were divided into three different ecosystems; the River water of Rosetta branch (fresh sector), estuary (saline/brackish sector) and Mediterranean Sea (saline sector). Discharge of wastewater from domestic, agricultural and industrial activities represents the main sources of water pollution and deterioration of water quality in the study area. Good water quality is vital for ecosystem of both fresh and marine water. For assessing water quality, determination of parameters is important as pH, EC, OM and different nutrients (Table 2 and Figure 3 (a-d)).

Electrical conductivity (EC) recorded a remarkable fluctuation in its mean values within the studied environments recording 113350, 29266.67 and 764.3 µs/cm for Sea, estuary and fresh River Nile, respectively. It follows the following order; Sea > Estuary > River. Downstream area contained saline water where salinity is remarkably decreasing towards upstream. The estuary area has the characteristics of both environments (Sea and River) in regard of physicochemical characteristics of water. Present EC levels in fresh River Nile of Rosetta branch (682- 813 µs/cm) is higher than recorded by Ezzat *et al.,* 2012 (375.5-803.5 µs/cm). Further, estuary EC average (29266.67 µs/ cm) is higher than recorded by El-Amier *et al.,* 2015 (18663.2 µs/ cm). Elevated levels of EC in the River Nile might be attributed to the increased levels of wastewater discharge as a result of urban area increase.

Weak alkaline water samples were recorded within the three studied environments recording mean values of 8.2, 8.5 and 8.1 for Mediterranean, estuary and Fresh River, respectively. The more alkaline water samples were recorded in the estuary area. Present pH levels in the River Nile (8.06-8.44) are coinciding with the threshold limits identified in the Egyptian Law No. 48/1982 (7-8.5) but higher than recorded by Ezzat *et al.* (2012) in the same area (7.45-7.9). The pH measured in estuary (8.5) is higher than recorded by El-Amier *et al.,* 2015 (7.96) and Mostafa & Peters, 2016 (8.05). Present level of pH (8.13-8.29) in the Sea is matching with the range recorded by Abdel-Halim and Aly-Eldeen (2016) during winter season (8.03-8.35).

Similar fluctuation in levels of NO_3 and NO_2 was observed within the studied environments, recording the highest mean levels in estuary (553.5 and 228.35 µg/l) followed by fresh River section (495.78 and 110.39 µg/l) since the lowest levels were observed in the Sea water samples (41.45 and 30.5 µg/l), respectively. The extensive utilization of inorganic fertilizers containing nitrogen is one of the significant sources of nitrate ions in water resources (Taha *et al.*, 2004). However, the elevated levels of NO_3 an NO_2 in the estuary environment were highly influenced by the fish cages usage in this area. It was noticeable that the high concentrations of both ions were at El-Mahmoudia area due to drainage water discharge into this area. Levels of NO_2 in the River Nile are matching with findings of Ezzat *et al*. (2012) in the same area (≤ 200 µg/l) except site number 8 (594.35 µg/l). Elevated NO_2 level at site 8 might be due to the activities practiced in the lifting station adjacent to this site. On the other hand, present findings of NO_3 in the River Nile of Rosetta (115.85-1383.25 µg/l) are within accepted limits of the Egyptian Law No 48/1982 (≤45000 µg/l) and lower than findings of Ezzat *et al.,* 2012 (5710-37150 µg/l). Present NO_3 average in estuary (553.5 µg/l) is significantly lower than findings of Mostafa and Peters, 2016 (10300 µg/l) at the same area.

On the other hand, the recorded mean values of PO_4 were 3.21, 17.56 and 16.84 µg/l for Mediterranean, estuary and Fresh River, respectively. The lowest mean value was recorded in the marine environment which is related to the increasing plankton that feed on nutrient causing depletion to its concentration (Abd El-Hamid, 2017). High PO_4 levels were recorded in the estuary and fresh water whereas the domestic detergent and industrial sewage water are considered important sources of phosphorus in natural water (Taha *et al.,* 2004). Present concentrations of PO_4 in the River Nile samples (7.36-27.56 µg/l) are coinciding with records of Ezzat *et al.,* 2012 (< 200 µg/l) in the same area.

Silicate recorded mean values of 614.25, 2009 and 290.5 µg/l at fresh, estuary and Sea water, respectively. The high levels of silicate in water resources may be attributed to the degradation of dead diatoms and to increase in silicon solubility. The slight increase in silicate levels depends on the degradation of the diatoms and other microorganisms (Bailey – Watts, 1976).

Mean values of OM were 39, 36 and 37.16 mg/l for Mediterranean, estuary and Fresh River, respectively. For fresh water, high levels of OM may be attributed to human activities, industrial wastewater and dead aquatic plants. For estuary ecosystem, OM can be received from two major pathways; Allochthonous and Autochthonous. The Allochthonous OM is originated outside the estuary and transported into the estuary from watershed runoff and riverine inflow (i.e. primary source). Further, it might also originate from sea waters through tidal inlets (i.e. secondary source). It is generated generally through photosynthesis process by primary producers or by benthic OM regeneration. In estuary habitats, the dominant primary producers are phytoplankton, sea grasses, epiphytes, benthic microalgae and submerged aquatic vegetation (Nixon, 1995; Paerl, 1997).

Eutrophication is the process of increasing the rate of OM supply and nutrients to an ecosystem. Nutrient sources can be basically grouped into two categories; point and non-point sources. The point sources include waste-water treatment plants, sewage outfalls, industrial wastewater and storm water drains. Nonpoint sources are mainly watershed runoff, ground water, and atmospheric deposition (Pinckney *et al*., 2014).

The N/P ratio gives an indication to the limiting factor responsible for controlling eutrophication in aquatic environment. N/P ratio was calculated from the concentrations of nitrogen as nitrate and phosphorus as phosphate. The N/P ratio can be classified as follows; < 5 (N-limitation conditions), 5-10 (either N or P limitation condition) or > 10 (P- limitation condition) (Smith and Shapiro, 1980). In this study, mean values of N/P ratio were 12.91, 31.52 and 27.30 for Mediterranean, estuary and freshwater environments, respectively. This gives an indication that phosphorus is the limiting factor for bio-growth of algae in the studied environments.

3.3. Statistical analyses

The results of correlation coefficient (r) were evaluated by Ramadan (2003) as follow; 0.0 (no), 0.3-0.5 (low), 0.5-0.7 (medium), 0.7-0.9 (high) and 0.9-1 (very high). The three selected indices (NDVI, NDBI and NDSI) were used to assess the relationship between water quality and land use. Agricultural activities which have an impact on water quality were assessed using the vegetation index (NDVI) which identified the density of vegetation around the sampled sites. To assess the effect of human activities and domestic wastewater discharges on water quality, built-up index (NDBI) was used. This index identifies the urban areas around the investigated sites. On the other hand, relationship between land salinization and water quality was assessed using the salinity index; NDSI (Figure 4).

Table (3) shows the correlation coefficient between water quality characteristics and spectral land use indices. Silicates contributed to water salinity and showed a significant positive correlation (0.827) with electric conductivity (EC). Pollutants from the same source exhibited positive correlations with each other and with the source of pollution. Therefore, positive correlations were observed between EC and silicate (0.827), nitrate and nitrite (0.806), nitrate and silicates (0.460), nitrite and silicate (0.721), N/P and silicate (0.334), N/P ratio and nitrite (0.738), N/P and nitrate (0.897).

One of the significant sources of water nutrients in study area is the agricultural activities, therefore NDVI showed positive correlations (low to medium) with nitrate (0.416), nitrite (0.517), silicate (0.272) and N/P ratio (0.345). The extensive application of fertilizers in the agricultural areas significantly participated to water pollution by nitrogenous and phosphorus compounds (Elbeih and El-Zeiny, 2018).

On the other hand, sewage wastewater discharge from urban areas are considered one of the sources of water organic pollution thus a positive correlation was observed between NDBI and OM (0.488). Land degraded by salinization showed a low positive correlation with OM levels in water (0.246).

It was obvious that pollutants from the same sources are positively and significantly correlated (i.e. NO_2, NO_3). The cluster analysis indicated similarity in parameter levels in each environment (Figure 5). In regard of the mean values for investigated parameters between different habitats, ANOVA statistical analysis was calculated (Table 4). ANOVA results showed high significance ($p<0.05$) for electric conductivity and silicates, moderate significance for pH, phosphate, NDSI and NDVI and non-significance for nitrate, organic matter and NDBI.

2.4. Relationship between spectral data and water quality

The correlation coefficiant between water quality and spectral reflectance bands is shown in table (5). Significant correlations were observed between spectral bands with electric conductivity, nitrate and phosphate. For EC, significant positive correlations were recorded with B1, B2, B3 and B4 recording 0.96, 0.97, 0.97 and 0.80 respectively. However, it showed significant negative correlations with B5 and B6 recording -0.92 and -0.79, respectively. Nitrate showed sigificant negative correlations with B1 (-0.61), B2 (-0.59) and B3 (0.95). Further, phosphate showed significant correlations with all visible bands (B2-B4).

These significant relations could be used for calculating water quality. This simply means that the spectral image can be converted into water quality characteristics. This advantage has been used in this study, based on regression analyses, to build an innovative model for phosphate in water (Figure 6). Phosphate was selected due to its high importance in water as a pollutant and as a bio-factor for the growth of algae. The model (algorithm) was generated based on the spectral reflectance of band 2 (Blue, 0.4526 µm) which exhibited a high positive correlation with water phosphate (0.720). The predicted phosphate (calculated from the model) showed also a high positive correlation with the laboratory measured phosphate (0.721). Formula of the generated algorithm is;

Phosphate (ppb)= - 719.44* Band 2 (0.4526 µm) + 86.981

Water is a dynamic environment; its quality is changeable and significantly impacted by different natural and anthropogenic factors. Therefore, the spectral reflectance of water varies according to water quality. Although there was a temporal change in the spectral values of each band in the same pixels (Figure 7), they were highly correlated (>0.6) in most of the investigated bands between 2017 and 2018 (0.39).

The developed model for phosphate was used to monitor the changes in its levels between 2017 and 2018. A similar fluctuation in phosphate levels (R= 0.79) was observed between 2017 and 2018 (Figure 8). This confirms that pollution sources have a continuous impact on water quality in the study area.

The generated model requires more assessment and validation to be applicable in similar environments. Although remote sensing is not so accurate as laboratory investigations in water quality studies, it gave the advantage of spatiotemporal assessments in inacessible areas or in areas which are difficult or impossible to be reached for sampling and analyses using the conventional methods.

Table 1. Description of water sampling locations

No	Coordinates		Description
	X	Y	
Mediterranean Sea Samples			
1	31.48	30.39	East of downstream point
2	31.47	30.36	Downstream point
3	31.46	30.36	West of downstream point
4	31.45	30.36	West of downstream point
Estuary Samples			
5	31.37	30.43	Rasheed bridge, fisheries, closest point to the Sea
6	31.37	30.44	Ezbet Henedy, agricultural activities are practiced
7	31.35	30.45	Industrial area, brick factories, some buildings, fisheries
Fresh River Nile Samples			
8	31.30	30.52	Close to lifting station of El-Deba
9	31.19	30.52	Residential area, close to electricity station of El-Mahmodia
10	31.13	30.64	Close to Desouk bridge, adjacent to residential area
11	31.12	30.65	Beneath Desouk bridge, close to fishing boats
12	31.11	30.66	A complain received from the discharge of domestic and industrial wastewater in close areas, brick factories
13	31.10	30.69	Very close to residential areas, few vegetation, Nile is very narrow at this area, Nile Rose plants
14	31.08	30.71	The whole surrounding area is residential which is very close to the Nile, turbid water, Nile Rose plants
15	31.07	30.72	Clear water, close to a worship place (Mosque)
16	31.03	30.72	Urban area, close to commercial places (coffee shop and supermarket)
17	31.01	30.74	At Kafr El-Sheikh boundaries, fishes were dead and flowing on water surface
18	30.92	30.78	Few vegetation, close to Kafr El-Zayat, urban area
19	30.90	30.77	Urban area, closest point to Kafr El-Zayat

Table 2. Water quality characteristics in the three studied ecosystems

Water Type	No.	EC (µs/cm)	pH	Nutrients (µg/l)				OM (mg/l)	N/P ratio
				NO_3	NO_2	SiO_4	PO_4		
Mediterranean Seawater	1	119100	8.25	62.76	23.77	619	5.21	72	12.05
	2	97000	8.13	40.24	68.51	767	4.59	28	8.77
	3	118800	8.3	31.4	16.89	642	2.14	24	14.67
	4	118500	8.29	31.4	12.83	429	0.92	32	34.13
	Mean	113350	8.2	41.45	30.5	614.25	3.21	39	12.91
Estuarine water	5	24800	8.67	581.75	315.95	2583	26.96	40	21.58
	6	29600	8.41	661.05	245.55	1638	14.08	30	46.95
	7	33400	8.47	417.7	123.55	1806	11.64	38	35.88
	Mean	29266.67	8.5	553.5	228.35	2009	17.56	36	31.52
Fresh River water	8	740	8.42	1383.25	594.35	1589	11.64	18	118.84
	9	682	8.28	765.35	79.75	182	12.26	32	62.43
	10	714	8.13	304.7	70.4	105	18.38	8	16.58
	11	719	8.44	175.3	71.95	427	7.36	40	23.82
	12	770	8.09	437	54.75	224	15.92	6	27.45
	13	870	8.17	223	75.1	77	23.28	14	9.58
	14	777	8.06	324.4	51.6	266	15.32	110	21.17
	15	813	8.05	360.85	79.75	140	27.56	30	13.09
	16	811	8.19	313.45	86	182	24.5	70	12.79
	17	791	8.11	348.9	45.35	35	15.92	20	21.92
	18	771	8.14	115.85	51.6	77	17.16	30	6.75
	19	714	8.12	765.35	64.15	182	12.86	68	59.51
	Mean	764.3	8.1	459.78	110.39	290.5	16.84	37.16	27.30

Table 3. Correlation coefficient analyses between water quality and spectral indices

Parameter	EC	pH	Nitrate	Nitrite	Silicate	Phosphate	O.M	NDSI	NDVI	NDBI	N/P ratio
EC	1										
pH	0.192	1									
Nitrate	0.106	0.173	1								
Nitrite	0.292	0.144	0.806	1							
Silicate	0.827	0.229	0.46	0.721	1						
Phosphate	-0.016	-0.353	-0.28	-0.069	-0.002	1					
O.M	-0.02	-0.339	-0.086	-0.185	-0.044	-0.03	1				
NDSI	-0.273	0.033	-0.416	-0.517	-0.272	-0.085	0.246	1			
NDVI	0.273	-0.033	0.416	0.517	0.272	0.085	-0.246	-1	1		
NDBI	-0.355	-0.006	-0.332	-0.516	-0.392	0.032	0.488	0.744	-0.744	1	
N/P ratio	-0.221	0.329	0.897	0.738	0.334	-0.171	-0.096	-0.345	0.345	-0.135	1.000

Table 4. One way ANOVA style of water quality parameters among the different habitats at (P<0.05)

Parameter	Seawater	Estuary water	Freshwater	F-value	P-value
EC	111433.33^{a}	29266.27^{b}	774.33^{c}	169.94	0.00^{***}
pH	8.24^{b}	8.52^{a}	8.20^{b}	8.2	0.19^{*}
Nitrate	34.35^{b}	553.5^{a}	388.07^{ab}	4.56	0.63^{ns}
Nitrite	32.74^{b}	228.35^{a}	68.82^{b}	9.14	0.02^{*}
Silicate	612.66^{b}	2009^{a}	112^{b}	30.3	0.0007^{***}
Phosphate	2.55^{b}	17.56^{a}	17.57^{a}	6.65	0.03^{*}
OM	28^{a}	36^{a}	25.33^{a}	1.96	0.28^{ns}
NDBI	-0.22^{a}	0.20^{a}	-0.11^{a}	0.77	0.50^{ns}
NDSI	0.17^{a}	-0.26^{b}	0.31^{b}	6.82	0.03^{*}
NDVI	-0.17^{b}	0.26^{a}	0.31^{a}	6.82	0.03^{*}

Table 5. Correlation between spectral reflectance bands and water quality

	Parameters	**Spectral reflectance**						
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
Water quality	EC.	0.96	0.97	0.97	0.80	-0.92	-0.79	-0.43
	pH	0.15	0.14	0.15	0.16	-0.05	0.04	0.10
	Nitrate	-0.61	-0.59	-0.59	-0.54	0.43	0.33	-0.07
	Nitrite	-0.37	-0.35	-0.36	-0.36	0.24	0.26	0.04
	Silicate	-0.03	-0.01	0.02	-0.04	-0.03	0.12	-0.02
	Phosphate	-0.70	-0.72	-0.70	-0.58	0.72	0.65	0.42
	O.M.	0.04	0.03	0.09	0.17	-0.05	-0.16	-0.23

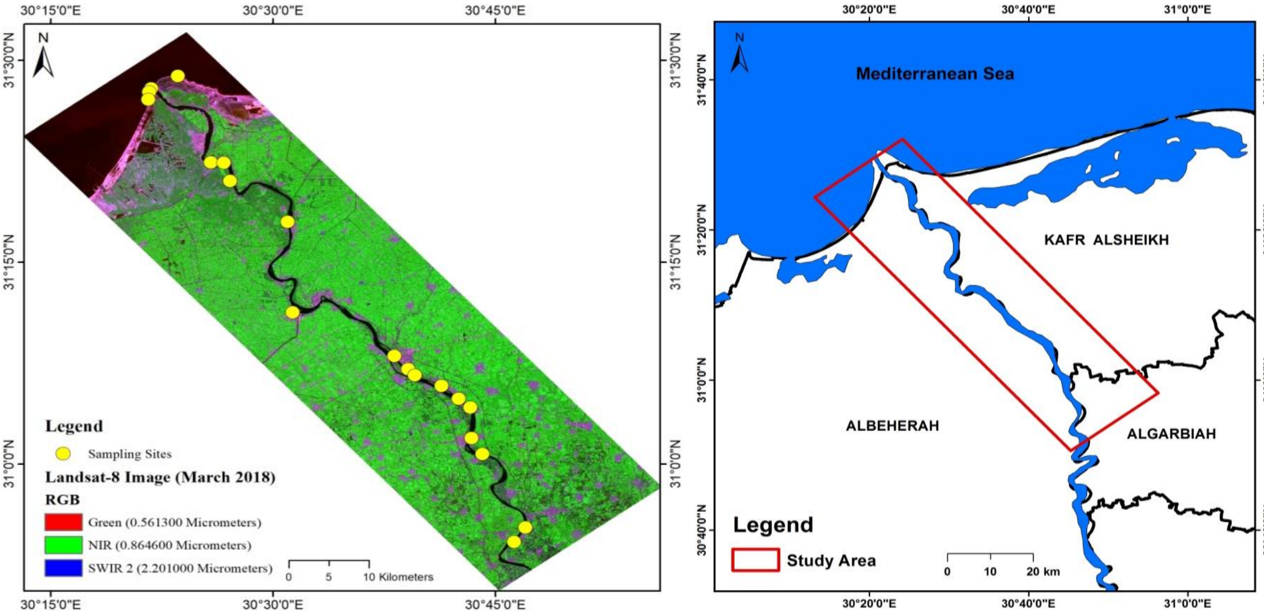


Fig. 1. Location map showing the area of study and the sampled locations

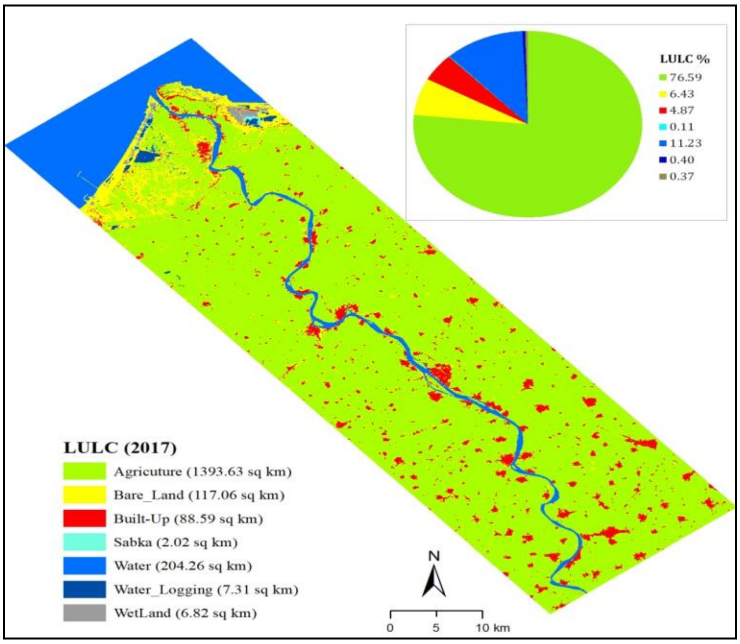
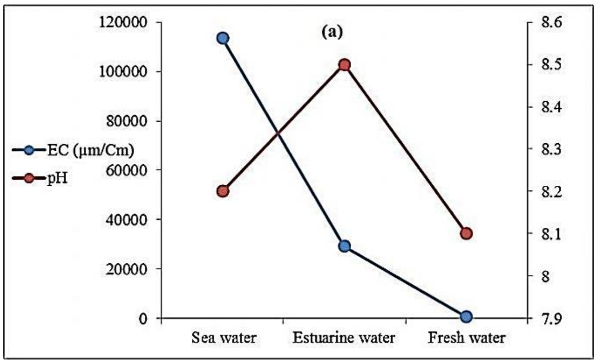
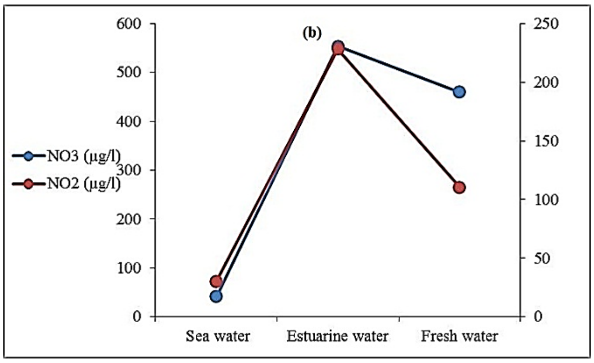
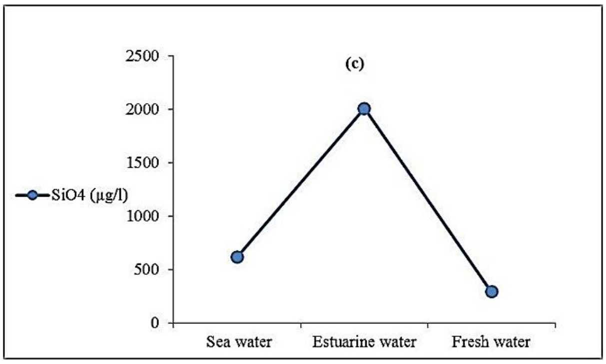
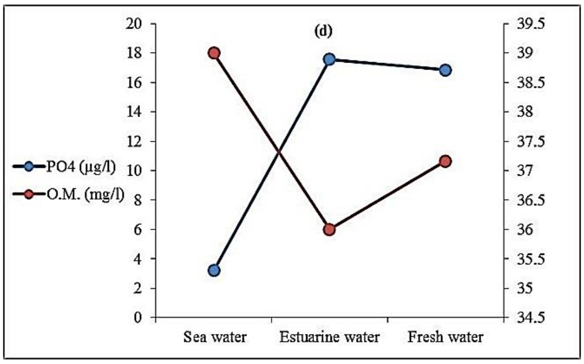


Fig. 2. Up-to-date LULC map for the study area









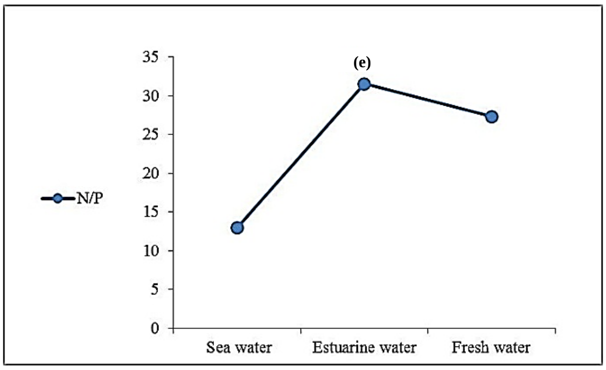


Fig. 3 (a-e). Mean distribution of EC, pH, NO_3, NO_2, SiO_4, PO_4, OM and N/P within different environments.

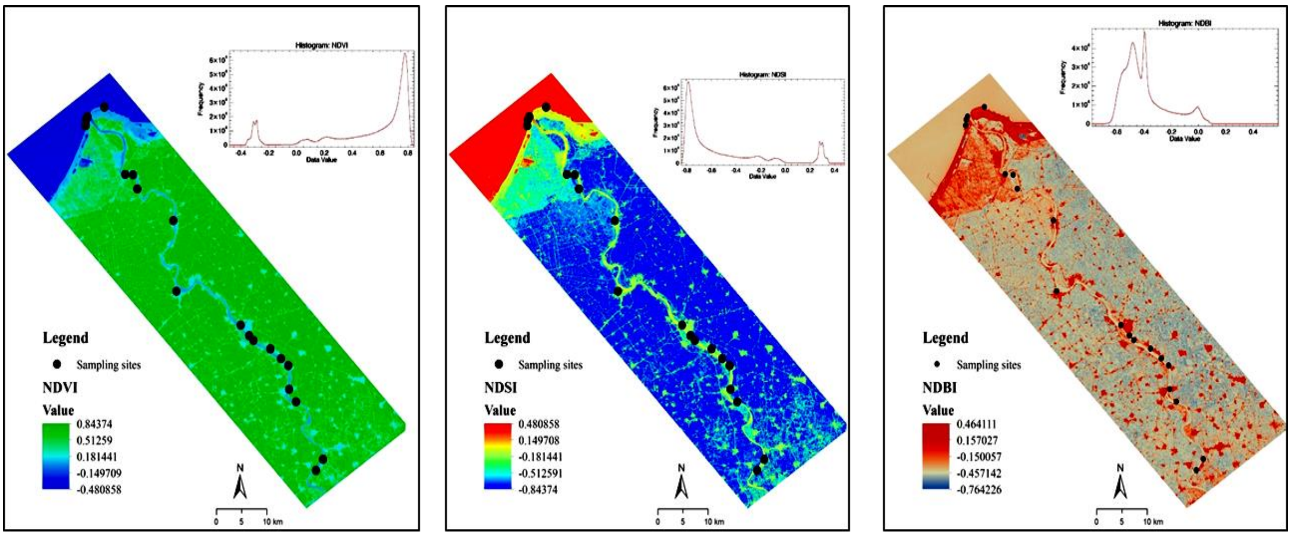


Fig. 4. Spatial distribution maps of NDVI, NDSI and NDBI in the study area

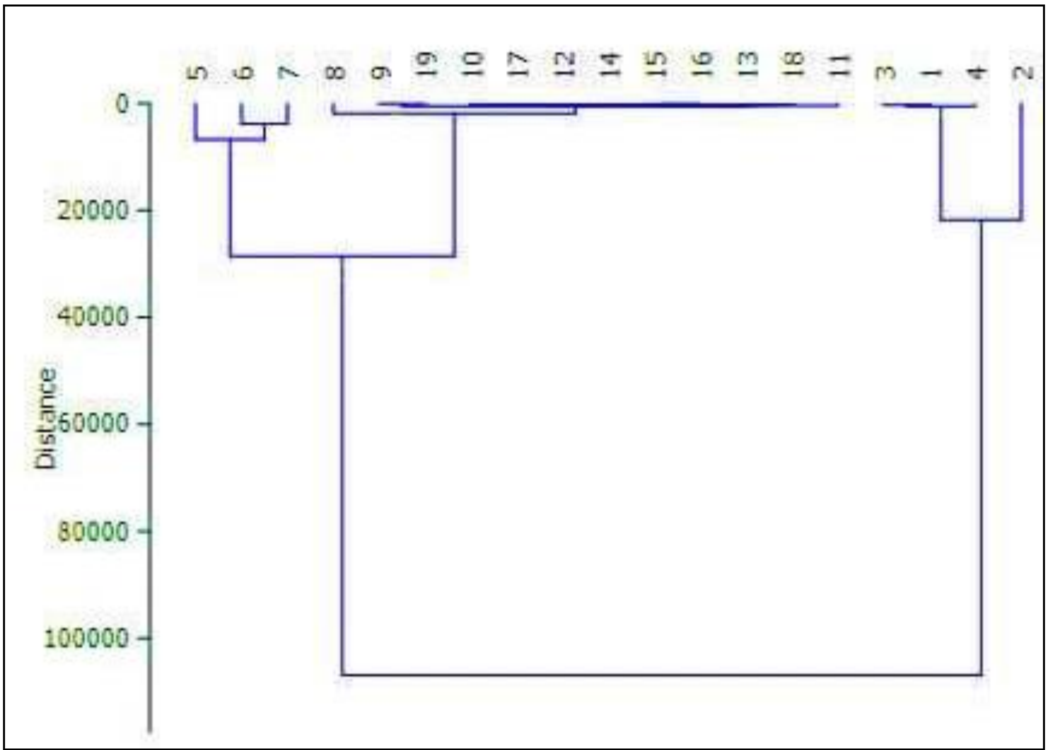


Fig. 5. Cluster analysis among water sampling stations within different environments

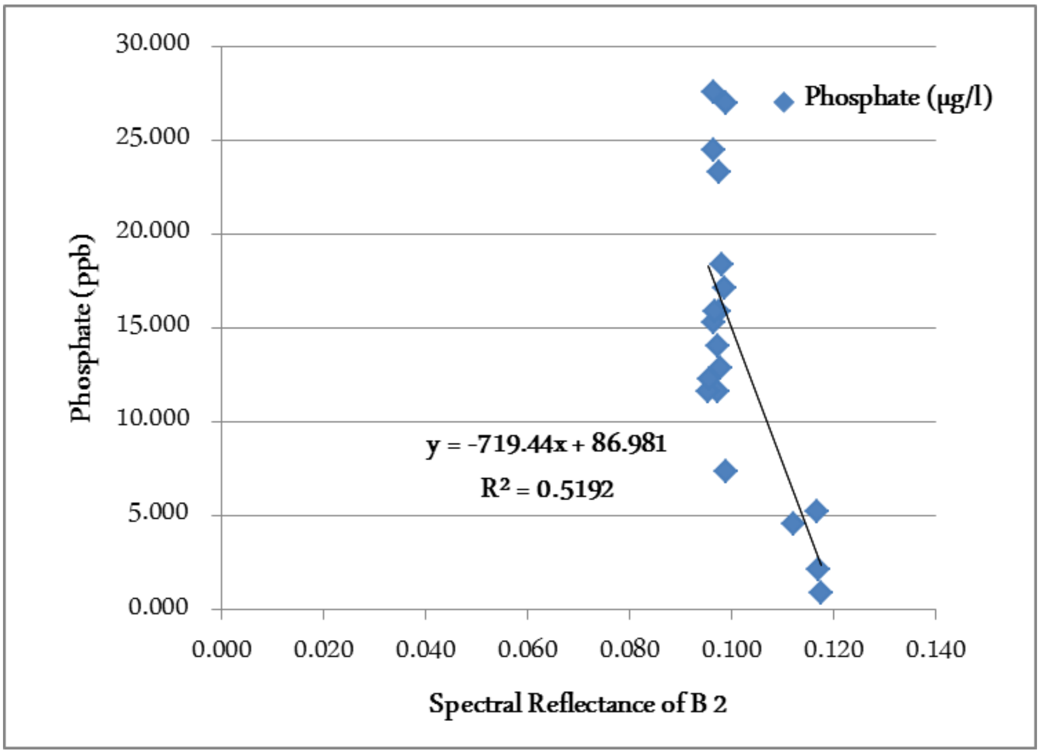
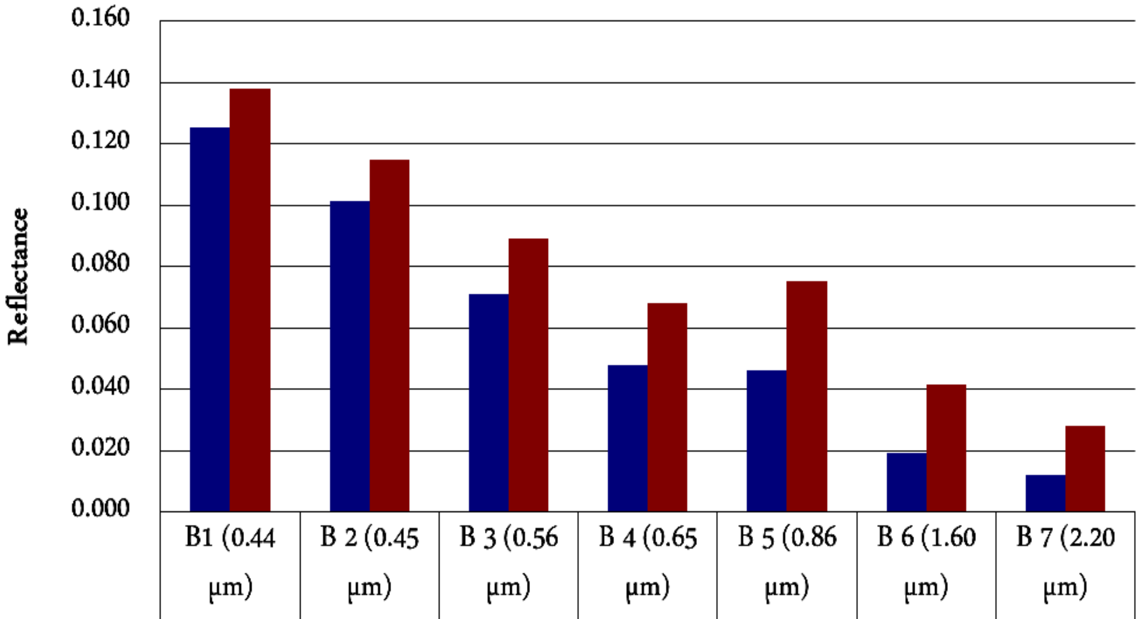


Fig. 6. Regression analysis between reflectance of blue band and phosphate



	B1 (0.44 µm)	B 2 (0.45 µm)	B 3 (0.56 µm)	B 4 (0.65 µm)	B 5 (0.86 µm)	B 6 (1.60 µm)	B 7 (2.20 µm)
Year 2017	0.125	0.101	0.071	0.048	0.046	0.019	0.012
Year 2018	0.138	0.115	0.089	0.068	0.075	0.042	0.028

Fig. 7. Temporal change in spectral reflectance average within the sampled locations

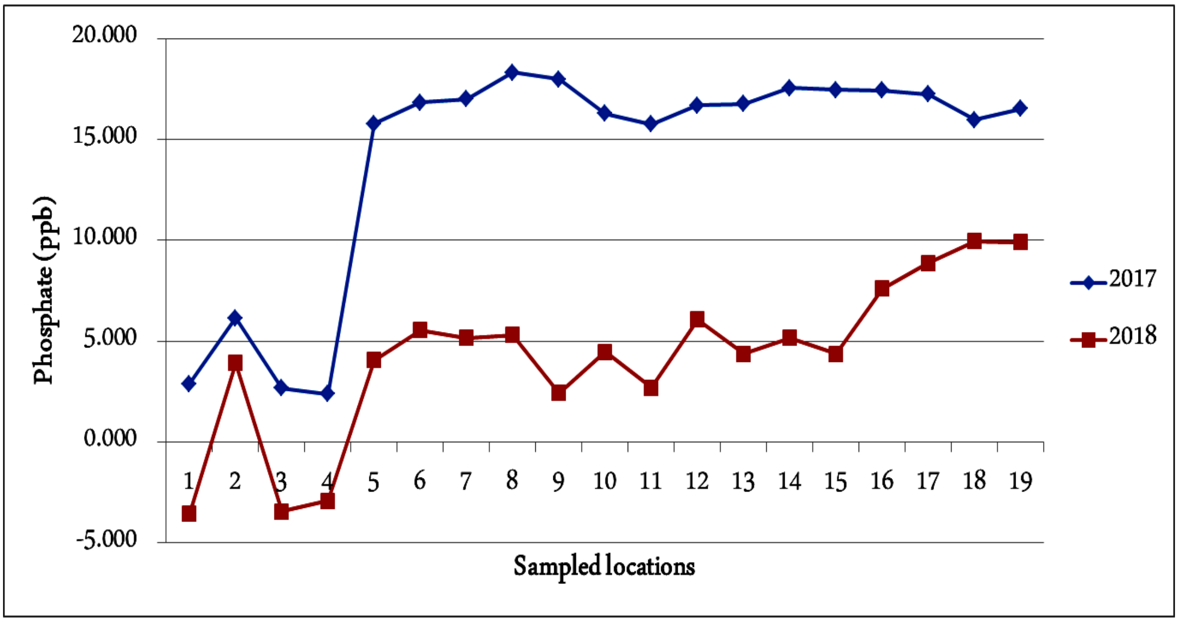


Fig. 8. Monitoring changes in phosphate between 2017 and 2018

4. Conclusion

The present research is an attempt to explore the impact of land uses, extracted from satellite Landsat data, on water quality in three ecosystems (fresh, estuary and saline) in Rasheed branch area, Egypt. Various fluctuations of water quality characteristics (pH, EC, NO_2, NO_3, SiO_4, PO_4 and OM) were observed in the studied environments as a result of the severity and the kind of land use activities. Estuary was the most exposed area to water quality deterioration either from sea water activities (e.g. shipping, fisheries) or from the different urban and agricultural activities distributed along the Rosetta branch. It can be concluded that spectral retrieved land use indices (e.g. NDBI, NDVI) could be utilized to identify the spatial distribution of the probable water pollution sources and gives a predictive qualitative insight about nutrient and organic pollutants in water resources.

In this study, the statistical relationship between spectral data and water quality was utilized for generating an innovative model for phosphate in water. This model was developed to monitor the change in water phosphate between March 2017 and 2018. Model results showed a similar temporal fluctuation in water phosphate levels within samples which confirms the continuous impact of pollution sources on water quality.

To minimize water pollution in Rosetta branch, the study highly recommends the necessity for the reduction of using chemical fertilizers which contributed to the elevated levels of contaminants in water resources. Further, it is necessary to manage the discharge of domestic wastewater into waterways of Rosetta branch which significantly increases the organic load in water resources.

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الملخص العربي

التأثيرات البشرية على جودة مياه نهر النيل والبيئة البحرية ، فرع رشيد باستخدام التحليلات الجيومكانية

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يهتم البحث بدراسة جودة المياه في ثلاث أنظمة بيئية مختلفة بفرع رشيد: مياه النيل العزبة ومياه المصب ومياه البحر باستخدام بيانات القمر الصناعي لاندسات والتحليلات المعملية. تم تجميع 19 عينة مياه يوم 2017/3/18 وتحليل الأس الهيدروجيني ، التوصيلية الكهربية ، السيليكات ، الفوسفات ، النيتريت ، النترات ، محتوى المادة العضوية ونسبة النيتروجين للفوسفور. تم الاعتماد على صورتين للقمر لاندرسات تم التقاطهم فى 26 فبراير 2017 و 1 مارس 2018 لعمل الدراسات الطيفية لهذه الدراسة. تم عمل معالجة للصور لانتاج خرائط لاستخدام الأرض ، مؤشرات الغطاء النباتي و العمران و الملوحة لتقييم الانشطة البشرية في المناطق المتاخمة لمنطقة الدراسة. تم عمل بعض التحليلات الاحصائية للربط بين استخدامات الارض وخصائص المياه فى عام 2017 ولرصد التغيرات الطيفية فى عام 2018 نتيجة لتغير خواص المياه. أظهرت النتائج معامل ارتباط ايجابي بين الغطاء النباتي مع النترات (0.416)، النيتريت (0.517)، السيليكات (0.272) ونسبة النيتروجين للفوسفور (0.345) والذى يؤكد تأثير الانشطة الزراعية على جودة المياه. بالرغم من أن نسبة المناطق السكنية تمثل حوالي 4.87 % من اجمالى منطقة الدراسة الا انها ساهمت فى زيادة مستويات المادة العضوية ، ظهر ذلك من خلال معامل الارتباط الايجابى بين المادة العضوية والمناطق السكنية (0.488). أظهرت متوسطات قيم النيتريت ، النترات ، الفوسفات ونسبة النيتروجين للفوسفور الترتيب التالي: المصب > المياه العذبة > مياه البحر ، بينما بالنسبة للمادة العضوية و التوصيلية الكهربية فكانت كالتالي: مياه البحر > المصب > المياه العذبة. تراوحت قيم نسب النيتروجين للفوسفور ما بين 12.91 الى 31.52 مما يشير الى أن الفوسفور كان العامل المحدد لنمو الطحالب في الثلاث بيئات. تم فى هذه الدراسة بناء نموذج مبتكر لحساب مستويات الفوسفات فى المياه بناء على المرئية الفضائية الملتقطة عام 2017 و تم تطبيقه على عام 2018 ولوحظ تشابه كبير ما بين عامى الدراسة فى مستويات الفوسفات فى المواقع المختلفة. يمكن استنباط أن تقنيات الاستشعار من البعد تلعب دورا هاما فى التحديد المكانى لمصادر التلوث المحتملة للمياه و في التقييم النوعى لمستويات التلوث بالمغذيات والملوثات العضوية.

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JOESE 5

Anthropogenic Impacts on Water Quality of River Nile and Marine Environment, Rosetta Branch Using Geospatial Analyses

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