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Using Vegetation Indices (NDVI, RVI, IPVI, and DVI) to Detect Physical and Chemical Parameters from Landsat-8(OLI) Image when Pixel Mixing Soil, Vegetation, and Water

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Abstract: Remote sensing provides an active and reliable means of collecting the data required, so as to map water quality. Besides providing an overall view, remote sensing can supply structure information about the parameters of water. The spectral reflectance of a field will vary with respect to changes in the sun elevation, season, and Quantities of clouds in the scene, and thus can be measured by multispectral sensors (OLI). In the present study NDVI, RVI, IPVI, and DVI have been used to identify 11 parameters included: acidity (PH), Total Dissolved Solids (TDS), Alkalinity(ALK), Electrical Conductivity (E.C), Calcium(Ca), Chloride (CL), Sodium (Na), Sulfate (SO4), Potassium (k), Total suspended solid (T.S.S), Total Hardness (TH) for Gharraf stream. The samples were taken to five stations with two seasons and at the same time took a satellite image on 4/FEB, 11 / MAY, where the five stations were represented reach of the stream (15-20) m width. This reach was correspondent to less than one pixel. The results show physical and chemical parameters cannot be calculated using vegetation index from Landsat-8 (OLI) images.
Keywords: parameters models, Al-Gharraf stream, NDVI, Landsat-8 OLI, vegetation indices

INTRODUCTION

Conventional water quality assessments(old method) are fixed to in situ collections from several spots on a long river or a wide lake for subsequent laboratory analyses [1].although this method is precise but requires fundamental time and effort for continuous observation .The goal of the essential paper was to develop an active procedure that would allow a GIS technician to integrate remote sensing and its capability of detecting surface water Spectral vegetation index measurement derived from remotely sensed monitoring offers great undertaking as a means to improve knowledge of water quality. Various mathematical combinations of satellite bands have been found Landsat-8 (OLI) have moderate spatial resolution (30 m*30m), multi-spectral images (nine bands), and a short revisit interval (16 days)to be sensitive indicators of the presence and condition of green vegetation, when the pixels were a mixture of water, vegetation, and soil, as a shown Figure [1]. These band combinations are thus referred to as vegetation indices. In this study, the dominant for vegetation indices to detection physical and chemical parameters using remote sensing and geographic information system(GIS). Vegetation indices are algorithms aimed at simplifying data from multiple reflectance bands to a single value[2].

MATERIALS AND METHODS

Study area

Gharraf stream is the longest branches of the Tigris River and derives its properties from it, which dates back to the Sumerian period (split King Antmina) of the Tigris River near the Dam of Kut. The cultivated land is estimated at (2151019) acres and amount of drinking water in these areas is estimated at 6429 m3 [3]. Gharraf stream passing Wasit and Nasiriya City. Nasiriya is located between latitude (30˚36′00″ _ 32˚00′00″ N) and longitude (45˚36′00″ _ 47˚12′00″ E).In this study, its limited to Branched part of the Shatt al-Shatra, which passes in Shatrah, Gharraf and ends in the marshes leading to Hammar as shown Figure (2).

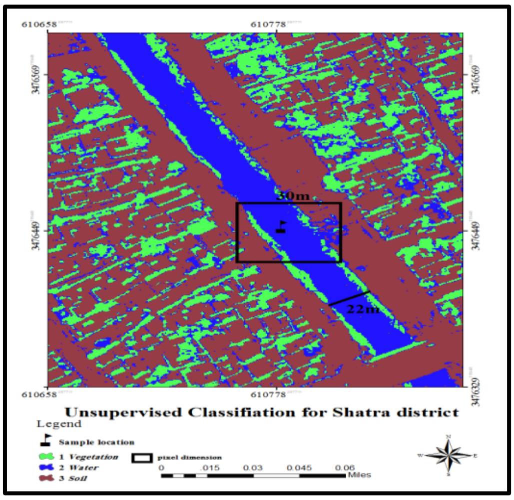

Fig-1: Unsupervised Classification appears pixel was a mixture water, vegetation and soil.

Water sampling

Eleven parameters water (acidity (PH), Total Dissolved Solids (T.D.S), Alkalinity(ALK), Electrical Conductivity (E.C), Calcium(Ca), Chloride (CL), Sodium (Na), Sulfate (SO4), Potassium (k), Total suspended solid (T.S.S), Total Hardness (TH))were examined during Feb 2017 and May 2017 from five different locations of Gharraf stream. Sampling stations are (3 samples from Shatra district) and(2 samples from Gharraf district). The samples were collected in bottle 1 L, polythene bottles without any air bubbles. The (PH, T.D.S and E.C) of the samples were measured in the field itself at the time of sample collection. Other parameters were obtained from a laboratory test, as shown Table (1) and Table (2).

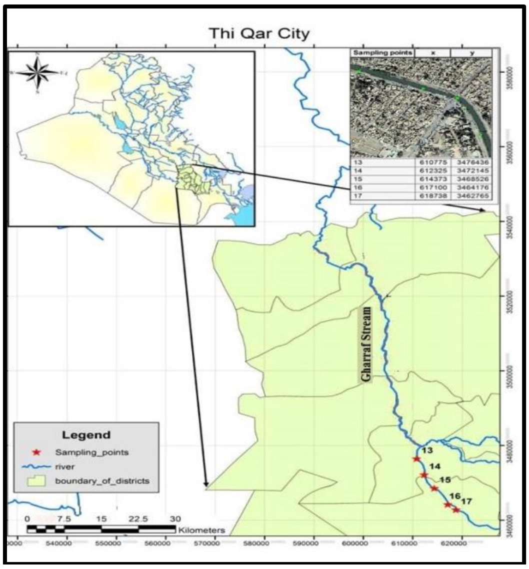

Fig-2: Location of the study area (Al- Gharraf stream)

Table-1: Test results using (PH-meter &oakton pcs testr 35) devices and Test results conducted in the Department of the Environment Water / Najaf Governorate (date: 4/FEB/2017)

ID	Name	Location		Physical Properties				CatIon (mg/l)				Anion (mg/l)		
		E	**N**	**Ph**	**EC(μs/cm)**	**TSS**	**TDS**	**Ca**	**TH**	**Na**	**K**	**Cl**	**So4**	**ALK**
Loc_13	Alshatra	610775	3476436	8.43	1481	28	1022	120	482	145.2	4.0	153	408	128
Loc_14	Alshatra	612325	3472145	8.58	1485	36	1018	120	482	144.8	4.0	149	413	128
Loc_15	Alshatra	614373	3468526	8.80	1484	28	1022	120	482	145.6	4.0	144	394	128
Loc_16	Algarraf	617100	3464176	8.67	1502	40	1036	121	486	145.2	4.0	149	398	130
Loc_17	Algarraf	618738	3462765	8.34	1532	56	1040	122	490	146.8	4.4	137	402	132

Table-2: Test results using (PH-meter &oakton pcs testr 35) devices and Test results conducted in the Department of the Environment Water / Najaf Governorate (date: 11/MAY/2017).

	Name	Location		Physical Properties				CatIon (mg/l)				Anion (mg/l)		
		E	**N**	**Ph**	**EC(μs/cm)**	**TSS**	**TDS**	**Ca**	**TH**	**Na**	**K**	**Cl**	**So4**	**ALK**
Loc_13	Alshatra	610775	3476436	8.4	846	36	450	76	304	75.9	2.4	93	205	76
Loc_14	Alshatra	612325	3472145	8.4	855	40	646	76	304	76.5	2.4	94	214	76
Loc_15	Alshatra	614373	3468526	8.6	881	36	602	77	308	89.7	3.9	98	208	78
Loc_16	Algarraf	617100	3464176	8.5	866	54	526	77	308	79.2	2.4	100	214	78
Loc_17	Algarraf	618738	3462765	8.5	872	16	628	77	308	76.5	2.4	102	220	78

DATA SET

Two scenes of Landsat-8 (OLI) data acquired in Feb and May were obtained from the US Geological Survey (USGS) Global Visualization Viewer. The images are obtained for the same year (2017). The obtained Landsat data (Level 1 Terrain Corrected (L1T) product) were pre-georeferenced to UTM zone 38 North projection using WGS-84 datum. Table (3) presents the specifications of Landsat-8 OLI images.

Table-3: Specifications of Landsat-8 OLI data

Satellite	Sensor	Path/Row	Year	Resolution (m)	Wavelength (µm)
Landsat-8	OLI	168/38	2017	30	Band 4: 0.636–0.673 Band 5: 0.851–0.879

IMAGE PRE-PROCESSING

Atmospheric and geometric correction

Landsat-8 OLI data 0.07 cloud for a scene. The images were precision corrected by geometric and radiometric.

Conversion of (dons) to top of atmosphere reflectance

The images acquire were converted to at-satellite reflectance using the Landsat calibration tool in Arc GIS 10.2. This conversion is important for studies regarding reflectance of river .The required information including: Reflectance multiplicative scaling factor, Reflectance additive scaling factor and Sun Elevation was obtained from the Landsat metadata files. Extracting the information from Landsat images, a single pixel (digital numbers, DN) was converted to reflectance according to following equation[4]:

$$\rho\lambda' = M^{p} * Qcal + A^{p} \quad \ldots (1)$$

Where:

$\rho\lambda'$ = Top-of-Atmosphere Planetary Spectral Reflectance, without correction for solar angle.

M^{p} = Reflectance multiplicative scaling factor for the band (REFLECTANCEW _ MULT_BAND_n from the metadata).

A^{p} = Reflectance additive scaling factor for the band (REFLECTANCE _ ADD_BAND_N from the metadata).

Qcal = Level -1 pixel value in DN.

Note:

$\rho\lambda'$ is not true TOA Reflectance because it does not contain a correction for the solar elevation angle . The conversion to true TOA Reflectance formula is:

$$P\lambda = \rho\lambda'/\sin(\theta) \quad \ldots (2)$$

Where:

$P\lambda$ = Top-of-Atmosphere Planetary Reflectance.

θ = Solar Elevation Angle (from the metadata, or calculated).

The Reflectance values for each Landsat-8 OLI band for the water sampling location on each date were extracted, as shown Table (4 and 5).

Table-4: Satellite image reflectance values in bands 4 and 5 at five different stations (date: 4/FEB/2017).

	B4	B5
Loc_13	0.1471	0.1373
Loc_14	0.1176	0.1530
Loc_15	0.1203	0.1757
Loc_16	0.0960	0.1148
Loc_17	0.1732	0.2020

B4=Red, B5=NIR

Table-5: Satellite image reflectance values in bands 4 and 5 at five different stations (date: 11/MAY/2017).

	B4	B5
Loc_13	0.2064	0.2089
Loc_14	0.1705	0.2220
Loc_15	0.1793	0.2670
Loc_16	0.1815	0.2425
Loc_17	0.2333	0.2783

B4=Red, B5=NIR

Application of water index

In order to detect the surface area changes of Gharraf stream in the period Feb and May, the water surface of the stream in each temporal image was extracted individually. In doing so, the performances of different satellite-derived indexes including Normalized Difference Water Index (NDVI), Ratio-Vegetation-Index (RVI),(IPVI) and (DVI) were examined for the extraction of surface water from Landsat data (Table 2).

Table-6: Vegetation indices

Index	Formula	Reference
Normalized Difference Water Index NDVI	NDVI=$\frac{NIR-RED}{NIR+RED}$	**5**
Ratio-Vegetation-Index (RVI)	RVI=$\frac{NIR}{RED}$	**6**
IPVI	IPVI=$\frac{NIR}{NIR+RED}$	**7**
DVI	DVI=NIR-RED	**8**

This process is done using (Arc GIS 10.2).

In this respect, the NDVI, RVI, IPVI and DVI indexes were calculated from Landsat-8 images (as a sample) to evaluate their performances for the extraction of parameters water. A vegetation threshold was manually applied to classify the images into three classes, land, water and vegetation. For visual interpretation of water bodies, the near-infrared (NIR) band is usually preferred, because NIR is strongly absorbed by water and is strongly reflected by the terrestrial vegetation and dry soil [9]. Thus, band 4 of Landsat data was selected in this study due to its higher ability to discriminate water and dry/land areas.

The five stations represented the reach of the stream (15-20) m width. This reach was equivalent to less than one pixel due to the pixels was a mixture of water, vegetation, and soil.

Correlation and regression analysis

Table-7a: Pearson correlation between spectral water index and water parameters for 4/FEB/2017 with five stations

		PH	E.C	ALK	T.H	Ca	CL	SO4	Na	K+	T.D.S	T.S.S
NDVI	Pearson Correlation	.717	-.034	-.093	-.093	-.093	-.410	-.429	.005	-.090	-.130	-.013
	Sig. (1tailed)	.087	.479	.441	.441	.441	.246	.236	.497	.443	.418	.491
	N	5	5	5	5	5	5	5	5	5	5	5
RVI	Pearson Correlation	.744	-.093	-.154	-.154	-.154	-.381	-.442	-.015	-.131	-.186	-.083
	Sig. (1tailed)	.075	.441	.402	.402	.402	.263	.228	.491	.417	.383	.447
	N	5	5	5	5	5	5	5	5	5	5	5
IPVI	Pearson Correlation	.717	-.034	-.093	-.093	-.093	-.410	-.429	.005	-.090	-.130	-.013
	Sig. (1tailed)	.087	.479	.441	.441	.441	.246	.236	.497	.443	.418	.491
	N	5	5	5	5	5	5	5	5	5	5	5
DVI	Pearson Correlation	.596	.067	-.010	-.010	-.010	-.555	-.433	.174	.071	-.087	.072
	Sig. (1tailed)	.144	.457	.494	.494	.494	.166	.233	.390	.455	.445	.454
	N	5	5	5	5	5	5	5	5	5	5	5

**. Correlation is significant at the 0.01 level (1-tailed).*. Correlation is significant at the 0.05 level (1-tailed).

To evaluate the nature and strength of the relationships, the reflectance index values of the image, that are the NDVI, RVI, IPVI and DVI were separately against eleven parameters. The coefficient of determination (R2) was used as a statistical measure of how successful the fitted regression model was in explaining the variation of the observed data. A statistical analysis was performed on the extracted from Arc GIS 10.2 as excel data. This data input to spss software for find the strength of the linear relationship between the two variables is the correlation coefficient(R), as shown Table (7a,b) and Table (8a,b).

Table-7b: Pearson correlation between spectral water index and water parameters for 4/FEB/2017 with five stations

		PH	E.C	ALK	T.H	Ca	CL	SO4	Na	K+	T.D.S	T.S.S
NDVI	Pearson Correlation	0.723	0.774	0.571	0.571	0.571	0.388	0.187	0.753	0.654	0.606	0.292
	Sig. (1tailed)	0.084	0.062	0.157	0.157	0.157	0.260	0.381	0.071	0.116	0.139	0.317
	N	5	5	5	5	5	5	5	5	5	5	5
RVI	Pearson Correlation	0.745	0.776	0.564	0.564	0.564	0.358	0.123	0.796	0.702	0.571	0.298
	Sig. (1tailed)	0.074	0.061	0.161	0.161	0.161	0.277	0.422	0.054	0.093	0.157	0.313
	N	5	5	5	5	5	5	5	5	5	5	5
IPVI	Pearson Correlation	0.723	0.774	0.571	0.571	0.571	0.388	0.187	0.753	0.654	0.606	0.292
	Sig. (1tailed)	0.084	0.062	0.157	0.157	0.157	0.260	0.381	0.071	0.116	0.139	0.317
	N	5	5	5	5	5	5	5	5	5	5	5
DVI	Pearson Correlation	0.805	.858	0.666	0.666	0.666	0.489	0.231	0.783	0.690	0.619	0.182
	Sig. (1tailed)	0.050	0.031	0.110	0.110	0.110	0.202	0.354	0.059	0.099	0.133	0.385
	N	5	5	5	5	5	5	5	5	5	5	5

**. Correlation is significant at the 0.01 level (1-tailed).*. Correlation is significant at the 0.05 level (1-tailed).

RESULTS AND DISCUSSION

In this study, regression analysis was not used to limit the physical and chemical parameters that were considered important explain water quality of Garran stream, because of the linear relationship (R) between the two variables is not significant. The near-infrared (NIR) is strongly reflected by the terrestrial vegetation and dry soil, but strongly absorbed by water.

CONCLUSIONS

Physical and chemical parameters cannot be calculated using vegetation index from Landsat-8 (OLI) images.

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