Iraqi Journal of Physics, 2022 *Vol. 20, No. 4, PP.10-17*

DOI:10.30723/ijp.v20i4.1021 *P-ISSN: 2070-4003*
E-ISSN: 2664-5548

Detection of Physical and Chemical Parameters Using Water Indices (NDWI, MNDWI, NDMI, WRI, and AWEI) for Al-Abbasia River in Al-Najaf Al-Ashraf Governorate Using Remote Sensing and Geographic Information System (GIS) Techniques

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Abstract

The purpose of this study was to find out the connection between the water parameters that were examined in the laboratory and the water index acquired from the examination of the satellite image of the study area. This was accomplished by analysing the Landsat-8 satellite picture results as well as the geographic information system (GIS). The primary goal of this study is to develop a model for the chemical and physical characteristics of the Al-Abbasia River in Al-Najaf Al-Ashraf Governorate. The water parameters employed in this investigation are as follows: (PH, EC, TDS, TSS, Na, Mg, K, SO_4, Cl, and NO_3). To collect the samples, ten sampling locations were identified, and the satellite image was obtained on the same day. Geographical information systems (GIS) are commonly used for the process of projecting the coordination often Stations Along Al-Abbasia River in the image of the satellite (Landsat-8) to then analyze the spectral reflections of the items and then treat the data obtained after the analysis process by using (SPSS) Software to find the correlation coefficient and regression equations. Because of the high connections between water metrics and the water index, four regression models were discovered. These models can be used to predict the four water variables (EC, SO_4, Cl, and NO_3) at any point along the Al-Abbasia River directly from the satellite image.

Article Info.

Keywords:
Water Indices, Remote Sensing, IS, Landsat-8, Al-Abbasia River.

Article history:
Received: Jun. 02, 2022
Accepted: Sep. 27, 2022
Published:Dec.01, 2022

1. Introduction

Water is an important natural resource for human survival and ecosystems, including coastal and freshwater areas (lakes, rivers, and groundwater). Over the last few decades, increased anthropogenic activity, particularly in industrial areas, has had an impact on water bodies. As a result, a river water quality monitoring program is required to promote public awareness by addressing the effects of existing and future pollution concerns [1]. Methods of field assessment of water quality indicators are often limited due to the high expense of data collection and laboratory analysis, particularly in the geographical and temporal domains [2]. An increasingly effective analysis of satellite imagery (landsat8 OLI) and geographic information systems (GIS) has developed as a significant tool for monitoring and predicting water quality parameters in rivers and streams over the last few decades [3].

The spectral index is a sum of surface reflections at many wavelengths [4]. Water parameters (PH, TDS, EC, Na, Mg, K, SO_4, NO_3, cl, and TSS) were collected from 10 locations along the Al-Abbasia River. In this investigation, the following indices were used: Normalized difference water index (NDWI), Modification of normalized difference water index (MNDWI), Normalized difference moisture index (NDMI), Water ratio index (WRI), and Automated water extraction index (AWEI). The wavelength spectra were extracted from the image.

1.1. Study Area

Al-Najaf Al-Ashraf city is located in southern Iraq, between latitudes (29° 50' 00" - 32° 21' 00") north and longitudes (42° 50' 00" - 45° 44' 00") east, as shown in Fig. 1. The Euphrates River, which splits into the Kufa and Al-Abbasia rivers roughly 8 kilometers before Al-Najaf Al-Ashraf province, is one of Iraq's main sources of water. The study area is in the Kufa district of Al-Najaf AL-Ashraf governorate, in the north-eastern part of the governorate. It is bordered to the north-east by Babil governorate, and by Al-Qadysia governorate to the south-east and from the west by the center of Kufa district. Before the river enters the province of Al-Qadysia at the district of Al-Salahia it is known as Shatt Al-Shamiya. The study are extends astronomically between longitudes (44.22 - 44.37) to the east and the latitude (31.58 - 32.11) north.

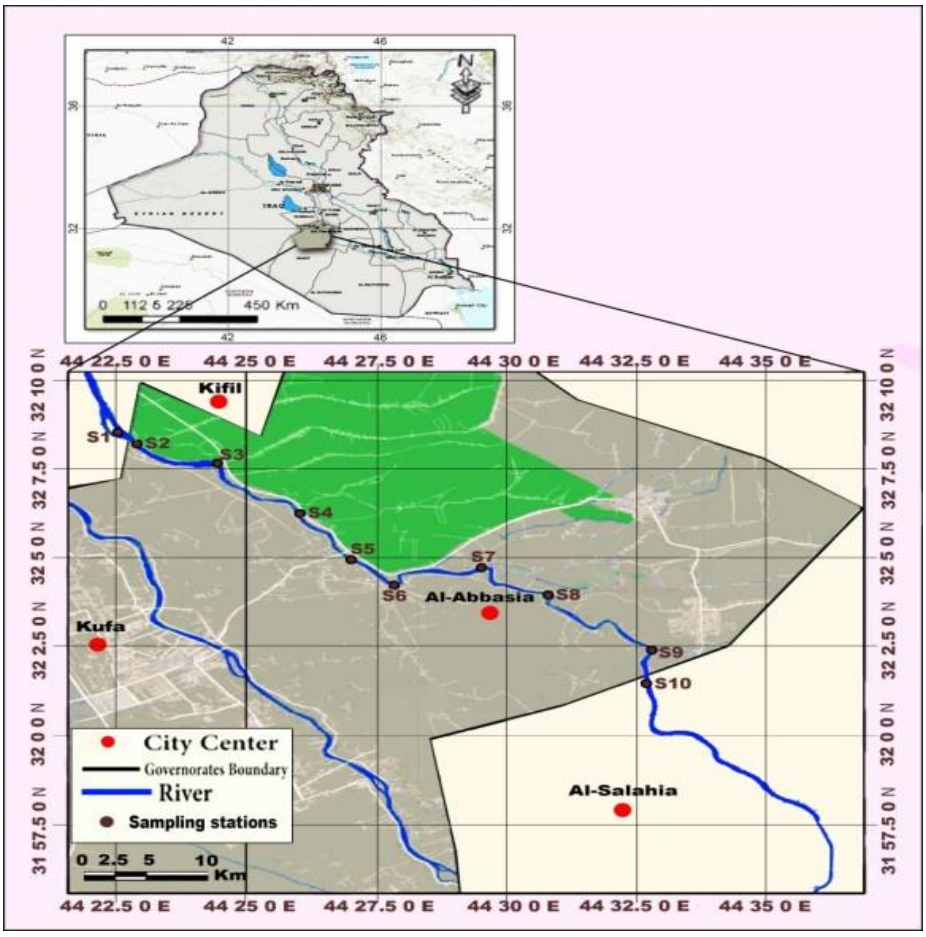

Figure 1: Study area and water sampling stations.

2. Materials and Methods

2.1. Samples Collecting and Laboratory Work

Ten water samples were taken from various geographical locations along the Al-Abbasia River on dates comparable with the research area's Landsat-8 OLI dates. Table 1 shows the physical and chemical parameters for 10 sampling stations along the Al-Abbasia River that were analyzed in the laboratory.

2.2. Software Work and Satellite Image Analysis

1- Using Software

In this study geographical information system (Arc GIS) software was used and digital maps were created by (Arc Map 10.4.1).

Table 1: Laboratory analysis results of studied samples.

Stations	Locations		Physical Characteristics				Cations mg/l			anions mg/l		
	X	Y	PH	EC(µs/cm)	TDS	TSS	Na	Mg	K	SO_4	Cl	NO_3
S1	44 22 53.35	32 7 55.24	7.8	1271.68	838.34	12.12	118.11	39.93	5.12	317.71	124.78	3.97
S2	44 23 13.86	32 7 39.26	7.9	1264.39	942.29	13.19	122.87	42.09	5.17	327.14	124.37	4.23
S3	44 24 41.48	32 7 8.01	7.6	1275.32	841.75	13.95	130.19	40.78	5.39	324.83	124.52	3.79
S4	44 26 12.83	32 5 46.44	7.7	1279.24	944.25	13.77	129.28	42.17	5.08	319.79	125.77	4.22
S5	44 27 10.99	32 4 36.71	7.6	1251.587	894.35	12.10	127.10	39.90	5.11	327.61	124.79	3.96
S6	44 27 54.97	32 3 57.41	7.7	1270.025	933.12	11.76	129.61	41.36	4.81	322.96	122.99	4.01
S7	44 29 34.76	32 4 24.06	7.9	1225.232	1010.32	12.57	131.71	40.68	4.86	323.97	122.36	4.09
S8	44 30 48.36	32 3 40.97	7.7	1259.247	921.03	12.91	117.20	39.88	5.3	326.70	122.23	3.92
S9	44 32 43.63	32 2 12.61	7.6	1280.502	892.25	13.79	129.61	41.30	5.77	325.03	124.08	3.89
S10	44 32 38.26	32 1 17.06	7.8	1291.398	911.79	13.04	124.02	42.15	5.15	327.16	124.47	4.13

2- Satellite Image Details

The Landsat-8 OLI satellite was used as it was timed to capture the aerial image of the study area on the same day as the samples were collected. The details of Landsat-8 satellite image were (30×30m resolution), on path 168, and row 38 and its date was 23/12/2021. The representative area of the study region was chosen from the satellite image for its clarity, ease of handling, and low data volume, as well as the ease with which the critical digital data processing activities in (Arc Map) software could be carried out.

3- Satellite Image Process

By treating reflection with special equations, processing and correcting the solar angular position in real value as in the upper atmosphere, and removing geometric distortions caused by changes in the scanner's speed and variations in its height, a true representation of the study site was obtained. After that the satellite image reflectance values at the sampling stations were calculated, as shown in Fig.2 and Table 2.

4- Application of Water Index (Bands Ratio Equations)

Data from the research area's multispectral bands were analyzed, and a one-way equation between the bands was used from a mathematical transaction between a defined number of bands to generate new digital images depicting specific study area attributes. In this way, water indices can be calculated and studied. In this

study, 5 water indices, as shown in Table 3, were extracted using 5 equations and for 5 bands which are (band3, band4, band5, band6 and band7).

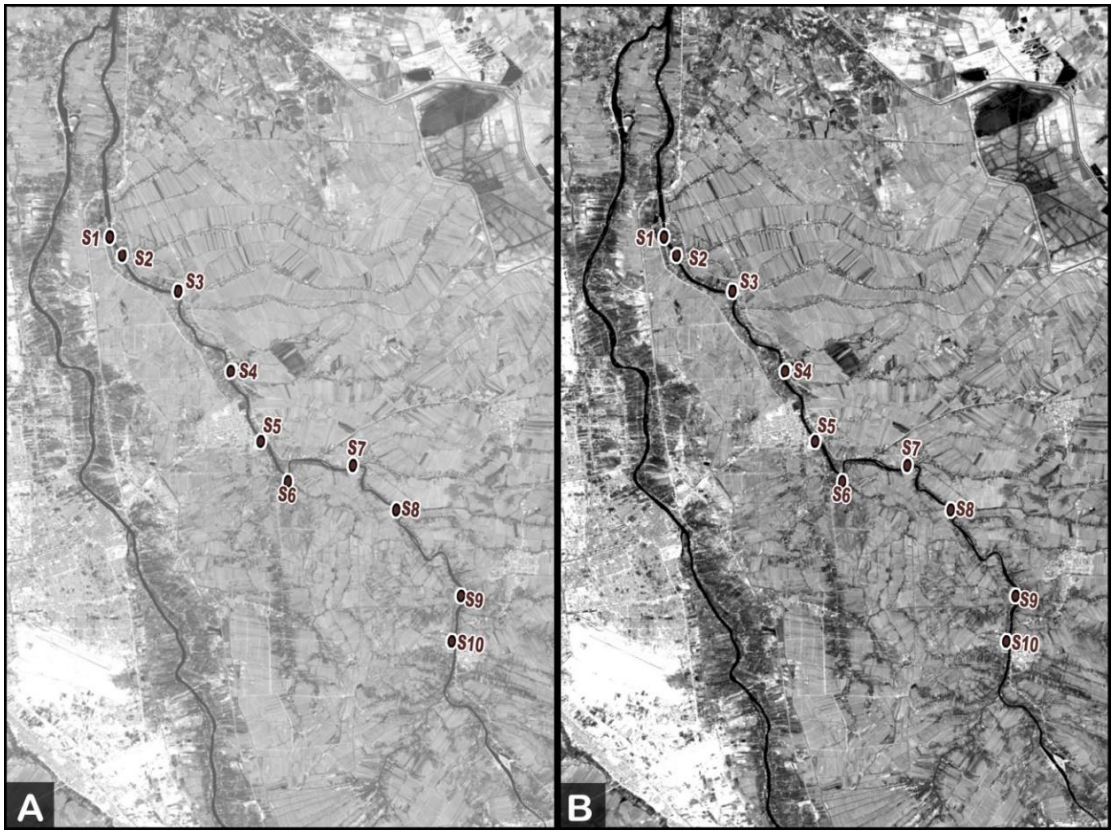

Figure 2: Satellite image of the study area: A- Before processing. B- After processing.

Table 2: Reflectance values of the satellite image in Bands (3-7) at 26 different stations (date: December 23, 2021).

Station	B3	B4	B5	B6	B7
S1	0.156458	0.139058	0.247185	0.206052	0.132779
S2	0.129533	0.079247	0.127670	0.093029	0.059133
S3	0.113409	0.054717	0.032900	0.028377	0.022364
S4	0.133045	0.112079	0.273897	0.195729	0.129958
S5	0.092710	0.047001	0.024811	0.024705	0.021406
S6	0.101224	0.051896	0.040456	0.026993	0.020501
S7	0.070254	0.013158	-0.005573	0.020608	0.021086
S8	0.102501	0.064135	0.039977	0.030133	0.026887
S9	0.096275	0.054983	0.034602	0.029813	0.022044
S10	0.116336	0.081323	0.112931	0.081110	0.056845

Table 3: Water indexes and equations.

Water indices	Equations	References
difference normalized water index, (ndwi))	$\text{NDWI} = \frac{\text{Green} - \text{Nir}}{\text{Green} + \text{Nir}}$	[5]
normalized difference modification the water index (mndwi)	$\text{MNDWI} = \frac{\text{Green} - \text{Swir2}}{\text{Green} + \text{Swir2}}$	[6]
moisture differential index normalized (ndmi)	$\text{NDMI} = \frac{\text{Red} - \text{Nir}}{\text{Red} + \text{Nir}}$	[7]
index of automated water extraction (awei)	$\text{AWEI} = 4 \times (\text{Green} - \text{Swir2}) - (0.25 \times \text{Nir} + 2.75 \times \text{Swir1})$	[8]
index of water ratio (wri)	$\text{WRI} = \frac{\text{Green} + \text{Red}}{\text{Nir} + \text{Swir2}}$	[9]

5- Analysis of Correlation and Regression (Statistical Analysis)

The NDWI, MNDWI, NDMI, WRI, and AWEI values of the image reflectance water index were compared to 10 distinct factors to assess the association's strength and quality. The correlation coefficient (R2) was employed as a statistical measure to assess how well the regression model described the variance of the observed data. (R2) values range from 0 to 1, with values near 1 indicating an effective regression model [10]. The satellite image bands' values and the results of laboratory analyses were correlated using the statistical tool (IBM SPSS Statistics 26); Microsoft Excel software was used to work out the study's linear mathematical equation.

3. Results and Discussion

The regression (R^2) method was used to determine the chemical and physical factors that were used, as well as to research and explain the water quality in the Al-Abbasia River. The field measurements, the date of obtaining the satellite image, and the ten sampling stations were entered into the regression equations. It appears from the values of (R^2) that with the exception of (PH, TDS, TSS, Na, Mg, and K), a high accuracy and a high correlation coefficient was obtained for (EC, SO_4, Cl, and NO_3) where the values of (R^2) were (0.691, 0.843, 0.643, and 0.612), respectively. The Pearson correlation results between water indices and parameters of water, and regression model (R^2) are shown in Table 4 and Table 5.

Table 4: Pearson correlation between water indices and parameters of water for the studied sampling stations.

Water Indices	Correlation details	PH	EC	TDS	TSS	Na	Mg	K	SO_4	Cl	NO_3
NDWI	Pearson Co	-0.080	-.715*	0.354	-0.165	0.462	-0.407	-0.062	0.429	-.698*	-0.422
	Sig. (2-tailed)	0.826	0.020	0.316	0.648	0.179	0.243	0.865	0.216	0.025	0.225
	n	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0
MNDWI	Pearson Co	-0.408	-0.299	0.027	-0.091	0.334	-0.302	0.199	.651*	-0.590	-0.608
	Sig. (2-tailed)	0.242	0.402	0.941	0.803	0.346	0.396	0.582	0.041	0.073	0.062
	n	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0
NDMI	Pearson Co	0.290	-.831*	0.580	-0.179	0.435	-0.293	-0.282	0.143	-.638*	-0.090
	Sig. (2-tailed)	0.416	0.003	0.079	0.621	0.209	0.411	0.430	0.693	0.047	0.804
	N	10	10	10	10	10	10	10	10	10	10
AWEI	Pearson Co.	-0.302	-0.294	0.106	-0.054	0.295	-0.217	0.184	.759*	-0.612	-0.507
	Sig. (2-tailed)	0.396	0.409	0.771	0.883	0.408	0.548	0.611	0.011	0.060	0.135
	N	10	10	10	10	10	10	10	10	10	10
WRI	Pearson Co.	-0.043	-.760*	0.393	-0.150	0.511	-0.406	-0.117	0.308	-.658*	-0.377
	Sig. (2-tailed)	0.907	0.011	0.261	0.679	0.131	0.244	0.748	0.386	0.039	0.283
	N	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0

* High values of Pearson correlation between water indices and parameters Shown with star mark.

Table 5: Regression model (R^2) between water parameters and water indices for the studied sampling stations.

Parameters	Model	R^2
EC	$EC = 29.344NDWI + 1275.931$	0.511
	$EC = 1.454NDWI - 19.386NDMI - 1271.288$	0.691
	$EC = 0.848NDWI - 19.500NDMI + 0.250WRI - 1271.288$	0.691
SO_4	$So4 = 38.529MNDWI - 33.110AWEI - 342.171$	0.843
Cl	$Cl = 3.191NDWI - 1.779NDMI - 3.445AWEI - 123.448$	0.588
	$Cl = 10.462NDWI + 1.509NDMI + 0.494AWEI + 3.419WRI - 119.867$	0.643
NO_3	$NO3 = 1.929MNDWI - 1.093AWEI - 4.908$	0.612

4. Conclusions

Some physical and chemical properties of water can be estimated using remote sensing technologies and water indices from Landsat-8 satellite photos. From the results of this study and after extracting the Regression model (R^2) between indices and parameters of water for the studied samples, where a high correlation coefficient was obtained between some parameters (EC, SO_4, Cl, and NO_3) and water indices (MNDWI, NDWI NDMI, AWEI, and WRI), and from results of the spectra of satellite image, it can be concluded that this correlation can be relied on in the study of these parameters in the future without the need for direct laboratory analysis. It is worth noting that the reflection in the surface of the water depends on the reflection of

the sky and also on the colour of the water content depending on decomposing chemicals or living organisms at the bottom of the river, and this is the reason for making corrections and processing operations on the aerial image to obtain the real reflections without any effects.

Acknowledgements

The authors would like to thank the department of Geology, College of Science, University of Baghdad.

Conflict of interest

Authors declare that they have no conflict of interest.

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التحري عن المعاملات الفيزيائية والكيميائية باستخدام مؤشرات المياه (NDWI, MNDWI, NDMI, WRI, and AWEI) من خلال تطبيق تقنيات الاستشعار عن بعد ونظام المعلومات الجغرافية (GIS) لشط العباسية في محافظة النجف الأشرف

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الخلاصة

أجريت هذه الدراسة من خلال تحليل البيانات المأخوذة من صورة القمر الصناعي لاندسات 8 ونظام المعلومات الجغرافية (GIS) لإيجاد العلاقة بين معايير المياه التي تم تحليلها في المختبر ومؤشر المياه الذي تم الحصول عليه من تحليل صورة القمر الصناعي للقمر الصناعي لمنطقة الدراسة. والسبب الرئيسي لإجراء هذا البحث هوإيجاد نموذج للمتغيرات الكيميائية والفيزيائية لنهر العباسية في محافظة النجف الأشرف. المعلمات المائية الت يتم استخدامها في هذه الدراسة هي (TSS, Na, Mg, TDS, EC, PH, SO_4, Cl, NO_3 K,) تم تحديد 10 محطات لأخذ العينات وفي نفس اليوم تم التقاط صورة القمر الصناعي. تم استخدام نظم المعلومات الجغرافية (GIS) في عملية إسقاط إحداثيات عشر محطات على طول نهر العباسية في صورة القمر الصناعي (لاندسات 8) لتحليل الانعكاسات الطيفية للعناصر ومن ثم معالجة البيانات التي تم الحصول عليها بعد ذلك. عملية التحليل باستخدام برنامج (SPSS) لإيجاد معامل الارتباط ومعادلات الانحدار. أدت الارتباطات القوية بين معاملات المياه ومؤشر الماء إلى إيجاد أربعة نماذج انحدار. يمكن استخدام هذه النماذج للتنبؤ بمتغيرات المياه الأربعة (EC, SO_4, Cl, NO_3) في أي نقطة على طول نهر العباسية مباشرة من صورة القمر الصناعي.