Water Quality index for Surface Water Assessment by using Remote Sensing and GIS Techniques, AL- Najaf, AL-Manathera district, Iraq

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Abstract. This study carried out in AL- Najaf province within Al-Manathera district that contents stream network, in dry season (2018), twenty samples collected and six physicochemical parameter analyzed for surface water in laboratory of environment and agriculture directorate in AL- Najaf Province. Six physicochemical parameter like Ec (mmho/cm), TDS(mg/liter), Ca^{2+}(mg/liter), Cl^{-}(mg/liter), So4^{2-}(mg/liter), and PH. Standards Iraq for irrigation purpose were used and inverse distance waited (IDW) interpolation has been utilized to create of six parameters spatial distribution map above. Raster calculator of Arc map GIS 10.2 software presented water quality index for surface water samples ranged between 54.2912 - 79.9387.

Key word: Water quality index , GIS, physicochemical parameters

1. Introduction

Water quality index (WQI) indicates the quality of water in terms of index number for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters were taken for calculation of water quality index [1]. WQIs have been mostly used in evaluation of potable water; very limited study has been carried out to evaluate the water for agriculture purpose [2]. WQI is a mechanism for presenting a cumulatively derived numerical expression defining a certain level of water quality [3]. In other words, WQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to management and the public in a consistent manner [4]. Most of the work on the WQI has been devoted to surface water such as streams and lakes with the intent of classifying the water for aquatic and recreational uses. Through this paper, an attempt has been made to carry out a review of important indices used for surface water quality assessment for steam network of AL-Manathera district that located within sedimentary flat east of Al-Najaf province. Higher EC in water creates a saline soil and deteriorates the soil health and reduces the crop yield. The salts apart from affecting the growth of plants also affect the soil structure, permeability and aeration which indirectly affect plant growth. Higher salt content in irrigation water causes an increase in soil solution osmotic pressure [5,6]. GIS is defined as a technique to capture, store, retrieve, analyses and predict [7]. The integration of WQIs with GIS provides the detailed, quick and reliable information for decision makes to adopt or
implement strategies related to water pollution and scarcity [8]. In this study six parameters have been chosen which are (electrical conductivity (EC), total dissolved solids (TDS), Ca$^{+2}$, Cl$^{-}$, SO4$^{2-}$, and, pH). The mentioned parameters in the method were chosen according to Iraq standard for irrigation water[9]. The results are represented in spatial distribution maps using ArcGIS software. The resulted WQI values are classified into three classes (good, moderate, and poor water). Thirteen samples have been collected and navigated by GPS GARMIN 72H. The GIS version 10.2 has been used to Geo-reference and digitize irrigation map that collected from water resources directorate in AL-Najaf province.

2. Methodology

2.1. Material and Software Used

a. The irrigation Map (scale is 1cm=1,750meters) in JPEG form Figure 1[10].

b. Landsat- 8 Satellite image of 30m resolution Figure2[11].

c. ArcGIS 10.2 software and Microsoft Office Excel of 2010.

d. ERDAS imagine version 9.2.

e. MATLAB version 7.7.0.

f. SAS planet release of 7/7/2018 which is downloaded from the Website: https://bitbucket.org/sas_team/sas.planet.bin/downloads

g. A GPS GARMIN 72H.

2.2. Study Area

AL-Manathera district center is located about 18 km south and south-western of AL- Najaf district center, is geographically located 44°17'30"- 44°32'30"E and 31°36'0"- 31°53'0" N see figure3. AL-Najaf province is located in south-west part of Iraq, covering an area of (185788.72) donums, the sub districts are located within of Al-Manathera district center are Al-Heera sub district, Al-Mishkahab sub district, and Al-Qadisiya sub district [12].

2.3. Maximum Likelihood Super Classification

Maximum likelihood is one of the most popular supervised classification method used with remote sensing image data. This method is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes, and that the input bands have normal distributions. However, this method needs long time of computation, relies heavily on a normal distribution of the data in each input band and tends to over-classify signatures with relatively large values in the covariance matrix. The distance (spectral distance) method calculates the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature, and the equation for classifying by spectral distance is based on the equation for Euclidean distance. It requires the least computational time amongst other supervised methods, however, the pixels that should not be unclassified become classified, and it does not consider class variability[13]. Accuracy assessment of classification can be defined as the process of comparing the classification with geographical data that are assumed to be true, in order to determine the accuracy of the classification process. Usually, the assumed-true data are derived from ground-truth data[13]. A set of reference pixels is usually used where points on the classified image for which actual data are (or will be) known. The relationship between these two compared information is commonly summarized in an error matrix (also known as a confusion matrix or contingency table). The number of rows and
columns in the error matrix should be equal to the number of categories whose classification accuracy is being assessed [14].

2.4. Collection of Surface water Samples and Physicochemical analyzed

In dry season (2018) the GPS GARMIN72H has been used to navigate of GCPs of 20 random samples in stream networks of AL-Manathera District, the parameters have been selected, Electrical Conductivity (EC), Chloride (Cl\textsuperscript{-}), Calcium (Ca\textsuperscript{2+}), Sulphate (SO\textsubscript{4}\textsuperscript{2-}), Hydrogen Ion Concentration (pH) and total dissolved solids (TDS). The inverse distance weighted (IDW) interpolation were used to create six parameters spatial distribution map see figure 2. Table 1, shows these parameters and their samples site, location, easting and northing. In laboratory of environment and agriculture directorate in AL-Najaf Province has been analyzed the parameters.

2.5. Water Quality Index Calculation

The WQI is computed from different various physicochemical parameters. To compute WQI, four steps are followed [15]. In the first step, the quality rating scale is assigned to the parameter which is also weighed according to its relative importance in the quality of water for irrigation purposes. These weights have a range from 1 to 5. The greatest weight assigned to parameter that has major importance in water quality assessment, while the smallest weight assigned to that parameter that may not be harmful. The standards for irrigation water as recommended by Iraq Standards and relative weight of physicochemical parameters are given in Table 2. The relative weight (RW\textsubscript{i}) was calculated using the following Equation (1) [16] [17].

\[
RW\textsubscript{i} = \frac{W\textsubscript{i}}{\sum\textsubscript{n} W\textsubscript{i}} \ldots \ldots \ldots (1)
\]

where \(RW\textsubscript{i}\) is the relative weight, \(W\) is the assigned weight of each parameter and \(n\) is the number of parameters. The relative weight \(WR\) values of each parameter are given in Table 2. In the third step, a quality ranking scale \(q\textsubscript{i}\) for each water parameter is calculated by dividing its concentration by its standard according to the guidelines of [18] and then multiplied by 100:

\[
q\textsubscript{i} = \left( \frac{C\textsubscript{i}}{C\textsubscript{s}} \right) \times 100 \ldots \ldots . (2)
\]

\[
q\textsubscript{i} = \left( \frac{C\textsubscript{o} - C\textsubscript{i}}{C\textsubscript{o} - C\textsubscript{s}} \right) \times 100 \ldots \ldots (3)
\]

\(C\textsubscript{o}\) and \(C\textsubscript{i}\) represent the observed and ideal values respectively. \(C\textsubscript{s}\) is the Iraq irrigation water standard for each chemical parameter according to the guidelines of [9] Table 2. In most cases \(C\textsubscript{i}\) is equal to zero except in certain parameters such as pH, dissolved oxygen etc.

In the fourth step, the Sub Index \(SI\textsubscript{i}\) of \(i^{th}\) parameter is determined in Equation (4) for each physicochemical parameter, which is then used to calculate the overall Water Quality Index WQI:

\[
SI\textsubscript{i} = W\textsubscript{i} \times q\textsubscript{i} \ldots \ldots \ldots \ldots (4)
\]

Finally, WQI is calculated by adding together each
sub index values of each water samples as follows:

$$WQI = \sum_{i=1}^{n} S_i \quad \cdots \quad (5)$$

The values of WQI are usually classified into three categories good water, moderate water, and poor water for irrigation purposes [19] as shown in Table 3. In this study, the range of the computed WQI values is varying from 54.2912 - 79.9387 and therefore, can be categorized into three types “good water” to “poor water for irrigation”. Table 3 shows the percentage of water samples that falls under different quality.

3. Results and Discussion

3.1. Water quality index

The computed WQI values range from 54.291- 79.938 and therefore, can be categorized into three types “good, moderate, and poor water”, see Table 3. The obtained WQI values were used for drawing the WQI map by using GIS software as seen in figure 3. Concerning the Table 3 it is clear that the good type represents the dominated water quality in the study area. Figure 3 reveals the spatial distribution of the different water qualities according to WQI values, were the green part represents the locations of the best available water quality in the study area then the yellow parts which represent the moderate type while the poor type was exhibited in red color.

3.2. Physicochemical Properties of Surface Water

The quality of surface water varies from site to site depending up on surface characteristics. The variations of water quality were discussed below.

- **Hydrogen Ion Concentration (pH)**
  According to table 1, the pH of the surface water samples varies from 6.64 to 8.15 with an average is 7.029 that is refer to the water is slightly alkaline, for all the sample sites were within the permissible limit given by SOI (8.6) Table 2, that is suitable for the irrigation uses.

- **Electrical Conductivity (EC)**
  For all the sample sites EC is located between 1.3 to 1.8 mmho\:cm with an average of 1.46 m\:cm which is listed within the permissible limit given by SOI (2.5 mmho\:cm).

- **Total Dissolves Solid (TDS)**
  Total dissolves solid has a range from 770 to 1229 mg\:liter with the average about 957.04 mg\:liter, which is located within the permissible limit has been given by SOI (2000 mg\:liter), that is suitable for the irrigation uses. From noticed that increased concentration of TDS in dry season due to increase of temperatures and decreased level of water in stream network as especially in samples of (SW 5, SW 11, SW 15 SW 16, SW 18, SW 20).

- **Calcium (Ca)**
  Calcium in surface water samples varies from 124.8 to 186 mg\:liter with an average of 150.11 mg\:liter, for all the samples it is within the permissible limit given by SOI (450 mg\:liter), that it is suitable for the irrigation uses. From noticed that the increased concentration of Calcium in the samples locations of (SW 5, SW 11, SW 15 SW 16, SW 18, SW 20).

- **Chloride (Cl)**
  Chloride in surface water samples varies from 150 to 177 mg\:liter with an average of 161.36 mg\:liter, for all the samples it is within the permissible limit given by SOI (250 mg\:liter), that it is
suitable for the irrigation uses. From noticed that the increased concentration of Chlorid in the samples locations of (SW 5, SW 11, SW 15 SW 16, SW 18, SW 20).

- **Sulphate (SO4)**

  Sulphate in surface water samples varies from 332 to 556.2 mg/liter with an average of 425.11 mg/liter, for all the samples it does not within the permissible limit given by SOI (200 mg/liter) that is unfit for the irrigation uses. From noticed that the increased concentration of sulphate in the samples locations of (SW 5, SW 11, SW 15 SW 16, SW 18, SW 20).

### 3.3. The Land Use and Land Cover Description

For Al-Manathera district center, there are totally six categories were classified in this district center. They are residential buildings, water bodies, orchards, agriculture lands, bare lands and green space. Figure 3 shows LULC the supervised maximum likelihood classification were surrounded projects of Al-Manathera district center with (Al-Heera sub district, Al-Mishkahab sub district, and Al-Qadisiya sub district). According to Table 4, agriculture lands are the highest area in this classification then followed by area of residential buildings, bare lands, green space, orchards and water bodies. For this study area, 256 random points have been taken to evaluate the accuracy of the of LULC classification. Table 5 presents the overall accuracy classification and the overall kappa statistics of 89.12% and 0.8552 respectively.

### 3.4. Water Quality index with Respect to LULC

Statistical analysis of Water Quality Index with respect to the Land Use / Land Cover shows in Table 5. These results gives Agriculture lands, Green space, Residential buildings and Orchards classes have maximum variation of WQI values than the Water bodies and Bare lands. However mean WQI value of all Land Use/ Land Cover classes having approximately same WQI value and standard deviation results shows that WQI is consistent throughout the LULC classes in the study area.

### 4. Conclusions

The Arc GIS software is powerful tool to create the spatial distribution maps of physicochemical parameters. The value of Water Quality Index ranges from 54 to 79 for the study area. The resulted WQI values are classified into three classes (good, moderate, and poor water). The poor water for irrigation purpose according to Iraq standards appeared in the north south and the east west part covers 11.841%, while the good and moderate water have been covered about 35.089-53.070% of the study area.

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Table 1: Parameters Analysis of Streams Network in AL-Manathera District Center
Table 2: Relative weight of Physicochemical parameters.

| Parameters          | Iraq Standards for irrigation purpose 2012 | Weight (Wi) | Relative weight (Wi) |
|---------------------|-------------------------------------------|-------------|----------------------|
| EC (mmho/cm)        | 2.5                                       | 5           | 0.2778               |
| TDS (mg/liter)      | 2500                                      | 4           | 0.2222               |
| Ca$^{+2}$ (mg/liter)| 450                                       | 1           | 0.0556               |
| Cl$^{-}$ (mg/liter) | 250                                       | 3           | 0.1667               |
| So4$^{2-}$ (mg/liter) | 200                                      | 2           | 0.1111               |
| PH                  | 4-8.6                                     | 3           | 0.1667               |

Table 3: Water quality classification based on WQI values.

| WQI  | Water quality  | Color in Map | Percentage of water samples |
|------|----------------|--------------|----------------------------|
| >64  | Good water     | Green        | 53.070                     |
| 64-69| Moderate water | Yellow       | 35.089                     |
| <69  | Poor water     | Red          | 11.841                     |
Table 4: Area (in donum) and Percentage for Al-Manathera district center

| Land Use/Land Cover    | Area in donum | Percentage |
|------------------------|---------------|------------|
| Residential buildings  | 92117.2       | 30.17      |
| Water bodies           | 1711.08       | 0.56       |
| Orchards               | 9298.8        | 3.05       |
| Agriculture lands      | 92354         | 30.25      |
| Green space            | 41944         | 13.74      |
| Bare lands             | 67914.4       | 22.24      |
| **Total**              | 305339.5      | 100        |

Table 5: Accuracy Assessment Supervised Classifications on Al-Manathera District Center

| Class name       | Residential buildings | Water bodies | Orchards | Agriculture lands | Green space | Bare lands | Row Total | Produces accuracy | User accuracy |
|------------------|-----------------------|--------------|----------|-------------------|-------------|------------|-----------|-------------------|---------------|
| Residential      | 38                    | 0            | 0        | 2                 | 3           | 0          | 43        | 88.37%            | 88.37%        |
| Water bodies     | 0                     | 4            | 0        | 0                 | 0           | 0          | 4         | 100.00%           | 100.00%       |
| Orchards         | 0                     | 0            | 5        | 0                 | 0           | 0          | 5         | 100.00%           | 100.00%       |
| Agriculture      | 2                     | 0            | 0        | 44                | 4           | 0          | 50        | 91.67%            | 88.00%        |
| lands            |                       |              |          |                   |             |            |           |                   |               |
| Green space      | 1                     | 0            | 0        | 2                 | 15          | 0          | 18        | 68.18%            | 83.33%        |
| Bare lands       | 2                     | 0            | 0        | 0                 | 0           | 25         | 27        | 100.00%           | 92.59%        |
| Column Total     | 43                    | 4            | 5        | 48                | 22          | 25         | 147       |                   |               |

Overall Classification Accuracy = 89.12%
Overall Kappa Statistics = 0.8552

Table 6: LULC Statistical

| LULC             | Minimum | Maximum | Range  | Mean  | Standard deviation |
|------------------|---------|---------|--------|-------|--------------------|
| Residential      | 54.349  | 79.725  | 25.376 | 63.102| 4.074              |
| Water bodies     | 56.784  | 74.121  | 17.337 | 63.500| 3.872              |
| Orchards         | 54.375  | 79.838  | 25.463 | 64.053| 4.071              |
| Agriculture lands| 54.291  | 79.766  | 25.475 | 64.944| 2.990              |
| Green space      | 54.336  | 79.794  | 25.458 | 64.905| 4.551              |
| Bare lands       | 54.373  | 78.958  | 24.585 | 65.424| 3.489              |
Figure 1: Land sat 8 image of Al-Manathra district center[11].

Figure 2: The Irrigation Networks in AL-Najaf Province[10].
Figure 3: Study area location
b. EC Spatial Distribution Map

a. PH Spatial Distribution Map
d. Calcium Spatial Distribution Map

c. Chloride Spatial Distribution Map
f. Sulphate Spatial Distribution Map
e. TDS Spatial Distribution Map

Figure 4 Spatial Distribution Maps of Physicochemical Parameters
Figure 5: Illustrates the LU/LC Supervised Classification of Study Area.

Figure 6: Water quality index Map of the study area.