The Egyptian Journal of Remote Sensing and Space Sciences xxx (2016) xxx–xxx

HOSTED BY

Contents lists available at ScienceDirect

The Egyptian Journal of Remote Sensing and Space Sciences

journal homepage: www.sciencedirect.com

Research Paper

Role of statistical remote sensing for Inland water quality parameters prediction

Abdelmalik K.W.

Department of Geology, Faculty of Science, Ain Shams University – Cairo, Egypt

ARTICLE INFO

Article history:
Received 8 October 2016
Revised 5 December 2016
Accepted 10 December 2016
Available online xxxx

Keywords:
Remote sensing
Regression
Inland water quality
ASTER

ABSTRACT

Understanding the statistical relations among the Advanced Space borne Thermal Emission and Reflection Radiation (ASTER) data and observed water quality parameters, in order to develop a mathematical relation for the precise prediction of the missing data in a given area, is the main aim of the present study. This should enable to establish a spatial distribution map for each parameter of water quality for the area. The method was applied to Qaroun Lake in the Fayoum depression of Egypt.

The water quality parameters obtained from ASTER data used in the present work are: Temperature, Turbidity, Hydrogen ion concentration (pH), Salinity, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total alkalinity, Total Organic Carbon (TOC) and Ortho-phosphorus.

18 water sample data were used in the study: 15 sample data for mathematical model construction, giving the relation between the ASTER values and the water quality parameters, while 3 samples data were used to test the obtained model.

The SPSS software of IBM was also used in the present research for the applied statistical analysis.

The analysis showed a significant correlation between the observed values and the remotely sensed data with $R^2 > 0.94$ and sig. < 0.01 in most cases. The calculated values resulting through the obtained equation showed a high accuracy: Root mean square error (RMSE) ranging from 0.8 to 0.014 and Standard Estimated Error (SEE) ranging from 0.9 to 0.0116.

ERDAS Imagine and ArcGIS packages were used for applying the obtained mathematical model and spatial distribution map to the Qaroun Lake.

1. Introduction

Water quality is an extremely important environmental factor as it affects human beings and their economic activities (e.g. Chen et al., 2009 and He et al., 2008). The major factor that affects the physical aspect (such as color) of the water is the concentration and distribution of fine suspended components and dissolved matter (Clark et al., 1980).

The traditional methods of measuring and studying water quality parameters of water bodies are expensive, both in cost and time, when compared to remote sensing techniques, especially if they deal with large areas.

Many authors have studied parameters affecting water quality by using remotely sensed data.

Recently many authors as Gholizadeh et al. (2016), Matthews (2011) and Kutser (2009) and many others; provided a detailed review of available types of remotely sensed data, which can be useful and effective in water quality studies. Authors mainly classify these data into 3 categories based upon their spatial resolution. Overall these categories are:

1. *High resolution data:* such as the data of IKONOS, Quick bird (4 m) and the Worldview Series (0.5–2 m).
2. *Moderate resolution data:* such as EO-1 Hyperion, ALI (10–30 m), Landsat series (15–120 m) and ASTER (15–90 m).
3. *Regional/Global resolution data:* such as NOAA-16 AVHRR (1000 m), ATSR-1,2 (1000 m), terra MODIS (250-1000 m) and seaWiFs (1130 m).

Broadly speaking many parameters have been considered by using a remote sensing approach, such as: *Physiochemical parameters* (pH, Temperature, EC, Salinity, TDS, TSS, Turbidity and Total alkalinity), *Organic parameters* (Biochemical oxygen demand BOD,

Peer review under responsibility of National Authority for Remote Sensing and Space Sciences.

E-mail address: Karim.abdelmalik@gmail.com

http://dx.doi.org/10.1016/j.ejrs.2016.12.002
1110-9823/

TOC, DOC, TIC) and *Microbiological parameters* (Total Colloform TC, Cholorophyll Chl-a). Of course the relationship between the water quality parameters and the radiance or reflection is affected by changing in one or more of these parameters. Moreover, it also affected by seasonal changing. So, any investigation deals with mentioned relation must be addressed to particular season and conditions.

Several authors have used and applied the regression statistical techniques in order to estimate and calculate water quality parameters as Khattab and Merkel (2014), Guan (2009), Hirthle and Rencz (2003), Coskun et al. (2001) and Choubey and Subramanian (1990).

The main aim of the present study was to explore several algorithms in order to determine the most suitable ones for the estimation of temperature, Turbidity, potential Hydrogen ions (pH), Electric Conductivity (EC), Total Dissolved Solids (TDS), Salinity, Total alkalinity, Orthophosphorous, Total Organic Carbon (TOC), for the Qaroun lake using the statistical approach and ASTER Data.

An additional goal was to map the water quality parameters by using estimated ones instead of conventional methods.

2. Study area and general geology

The Fayoum is an enormous depression located in the north eastern part of the Western Desert of Egypt, The Qaroun Lake occupies the lowest part of it. Qaroun Lake is laying between latitudes 29° 25′ & 29° 30′N and longitudes 30° 25′ & 30° 50′E extending over an area exceeding 200 km^2. It has an elongated shape, about 42 km., east-west and is about 10 km. in width. Qaroun Lake was declared a natural reserve by virtue of the Prime Minister decision No. 348 of 1989, with an aim to protect and conserve the biological, archaeological and geological diversity of the area.

The geology of the Fayoum area has attracted many authors as Beadnell (1905), Said (1962), Tamer et al. (1975), Swedan (1986, 1992), Abd El Motaal (1989), Abdel Hafez (1991), Nabawy (1998), El-Younsy et al. (1999), Azab (2001), Issawi et al. (2001) and Kusky et al. (2011). According to these previous works, the Fayoum depression occurs in a thick sedimentary series of Middle Eocene to Quaternary age.

Most of joints and faults observed by Kusky, strike NW-SE (Clysmic Trend) and E-W (Tethyan Trend).

3. Data and methodology

In the present study, both water samples and ASTER terra data were used in order to develop and drive an accurate simple algorithm to retrieve the water quality parameters for Qaroun Lake.

The sampling and water analysis were executed during May/June 2007, based on the APHA (1992) in sampling and testing methodology (Gad, 2009).

The current study uses water samples parameters of 18 locations representative to the Qaroun lake water body (Fig. 1). The parameters of 15 samples were used for processing the regression analysis to build up the equations expressing the relations between the parameters and the ASTER readings, while the remaining 3 samples were used for testing the accuracy of the developed equations.

The remotely sensed image, used in the present study, were those of ASTER Terra obtained from the US Geological Survey (USGS) via Earth Explorer site (*Earth explorer.usgs.gov*). The used scene were obtained with Path and Row 177/39 at an acquisition data of 24/6/2007 with zero cloud coverage.

(Fig. 2) illustrates the flowchart of the process cycle for the present work.

3.1. Remote sensing data preparation

3.1.1. Atmospheric correction

In any satellite imagery that observes the surface of the earth in the visible/infrared regions of the electromagnetic spectrum, the recorded signal contains two brightness types; the first due to the actual reflectance from the surface while the second one is due to the atmospheric effect and is considered as noise.

So, the atmospheric correction is an essential step of the image processing chain. Therefore, to obtain accurate and precise quantitative data using remote sensing, it is necessary to perform atmospheric correction (Tyagi and Bhosle, 2011; Chander et al., 2009; Liang et al., 2001; Lillesand et al., 2004).

In the current study the Aster (V/VNIR and SWIR) regions atmospheric correction process was executed using the fast line-of-sight atmosphere analyses of hypercubes (FLAASH) modules of ENVI 5.1, while for the thermal (TIR) region, the thermal atmospheric correction of calibration utilities of the same software version was used.

3.1.2. Precisely mapping of water lines

In order to extract and map the water line, the Normalized Difference Water Index (NDWI) which was developed by McFeeters (1996) was applied on the image. The output of the NDWI was found to range between −1 and +1, the threshold is, thus, zero. So, the water has positive values while non-water gets the negative ones. The effect of wet soil in Qaroun Lake's edge could be neglected specially in the season of study. Therefore, the lake border line can be obtained by vectorization of the water/non-water image. The raster data of the Qaroun Lake water body has been subset by the water line final result shape file.

3.2. Statistical analysis

The correlation and regression analysis techniques are widely used for studying and investigating the strength of the relationship – if any – between two quantitative variables. The correlation analysis quantifies the strength of the relation between a variable pars while the regression analysis develops the mathematical equation which express such relation.

In the present study, SPSS software package of IBM was used for executing both correlation and regression analyses in order to investigate and study the relationship between scoped parameters and remotely sensed data of the study area.

4. Results and discussion

4.1. Regression analysis

Various algorithms have been used by many authors to examine characteristic relationships between remote sensed data and water quality physiochemical, Organic and Microbiological parameters. (Khattab and Merkel, 2014; Elsaadi et al., 2014; Yüzügüllü and Aksoy, 2011; Coskun et al., 2008).

The present study includes the elaboration of regression analysis algorithms to examine and use the relations between the ASTER data reflectance bands and the water quality parameters of Qaroun Lake. The parameters used in such analysis are: Temperature, Turbidity, pH, Salinity, TDS, EC, Total alkalinity, TOC and Orthophosphorus.

Statistically, the created equations and relations were chosen according to three factors, which were: Adjusted Square Correction Coefficient (*R^2: Which is the percentage of the response variable variation that explained by the model, the higher value the better fitting of the model*), Standard Error of Estimation (*SEE: Standard Error of Estimation, which measurers the accuracy of the model in prediction,*