Developing Hydrological Model for Water Quality in Iraq Marshes Zone by using Geographic Information System and Remote Sensing

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Keywords: Monitoring; Water Quality; Remote Sensing; GIS; Finite Element Model.

Abstract. The mesopotamia marshlands constitute the largest wetland ecosystem in the middle east and western Eurasia. These marshlands are located at the confluence of Tigris and Euphrates rivers in southern Iraq. The construction dams by Turkish and Syrian for water storage as well as hydroelectric power generation along the Euphrates and Tigris rivers are led to reduce and deterioration water quality in Iraq's marshes. Moreover the first gulf war in 1980 and 1991 then 2003 wars on Iraq these led to deterioration and damaged majority of the marshes resources . In fact the marshes had been reduced in size to less than 7% since 1973 and had deteriorated in water quality parameters. The objective of this study to develop a new algorithm to retrieve water quality from Landsat-7 (TM and ETM) data based on differential equations algorithm. Moreover To derive two dimensional hydrodynamic effects on water quality patterns and trajectory movement of water quality distribution depending on finite element model such as two-dimensional depth averaged finite element hydrodynamic numerical model of resource management associates (FENM-RMA 2) and finite element water quality transport numerical model of resource management associates (FENM-RMA4) then using geographic information system to map hydrodynamic and the spatial variation of water quality parameters concentrations for total dissolved solids (TDS), total suspended solids (TSS) and salinity within Iraq's marshes in series time of different years.

Introduction

In the last century, there are several critical environmental problems have been raised up such as environmental pollution [10-22], poor water quality supply and sanitation, and soil erosions [7-12]. Man-made is beyond all the environmental crises due to destructive wars. It is not forgotten the three decades of the Gulf wars of 1980, 1991 and 2003, respectively, which led to several damages of the environment, especially in Arabian Gulf coastal waters and in Iraq. For instance, during the 1991 Gulf War, roughly one million oil tones blackened the Arabian Gulf (Fig. 1). Further, the three decades of war have destroyed Iraq's water resources management system. Thus, Iraq confronts complications to recognize the target of 91% of households using safe drinking water supply by 2015. Presently, 16% of households convey daily difficulties with supply and 20% use as an unsafe drinking water source. Furthermore, leaking sewage pipes and septic tanks pollute the drinking water network[16].

Fig 1. Oil spill blackened the Arabian Gulf.

In Iraq, there are other problems have raised up in last decades, such as water quality. American-Iraq war in 2003 has been affecting the water quality of rivers, streams, lakes and marshes in Iraq [1]. Further, inadequately treated sewage, poor land use practices, industrial waste waters discharges excessive use of fertilizers, and a lack of integrated watershed management are other factors impact water quality in Iraq [7]. The effects of these problems threaten ecosystems, endanger public health risks, and intensify erosion and sedimentation, leading to land and water resources degradation. Many of these negative effects arise from environmentally destructive development, a lack of information on the situation regarding water quality and poor public awareness and education on the protection of water resources [2,7,23].

However, clean water is essential to human survival as well as to aquatic life. Much surface water is used for irrigation, with lesser amounts for municipal, industrial, and recreational purposes only 6% of all inland water is used for domestic consumption. An estimated 75% of the population of developing nations lacks adequate sanitary facilities and solid waste is commonly dumped into the nearest body of flowing water. Pathogens such as bacteria, viruses and parasites make these waste materials among the world's most dangerous environmental pollutants, waterborne diseases are estimated to cause about 25,000 deaths daily worldwide [1-4].

Remote sensing techniques play major roles for monitoring and mapping, water quality[5,23]. With advances using remote sensing for data acquisition and the integrating finite element numerical model with the spatial capabilities of GIS and the spatial and temporal capabilities of remote sensing applications could provide a powerful tool for management and assessment to surface water quality problems in the marsh zone of southern Iraq[22].

Study Area

The mesopotamian marshlands of southeastern Iraq represents one of the largest wetland ecosystems in all of Asia and covered more than 19,000 km^2 and is formed by the confluence of the Tigris and Euphrates rivers. But in 2003 the marshes had been reduced in size to less than 7% of their 1973 levels 8,926 km^2 within Iraq. The geographical location of the study area southern Iraq at coordinates between latitudes ($32^{\circ}\ 00'\ 00''$ N-$32^{\circ}\ 30'\ 00''$ N) and longitudes ($46^{\circ}\ 00'\ 00''$ E-$48^{\circ}\ 00'\ 00''$ E).The major marshes in Iraq such as Al-Huweizah marsh is located east of Tigris river by approximate area 3,000 km^2 and Central marshes as Al-Qurna marsh are located in a triangular area between Tigris and Euphrates rivers by approximate area 2,800 km^2 and Abu-Ziriq is located north of Nasiriyah city on the western side of the former Central marshes with area 2,700 km^2 then Al-Hammer marsh is south of the Euphrates river, extend   from near Al-Nasiriyah city in the west to Al-Basrah city on Shat Al-Arab in the east with area 3,800 km^2 (Table 1),(Fig. 2).

Table 1. Length, width, depth and area of each marsh.

NO	Marsh	Depth (m)	Width(km)	Length(km)	Area (km^2)
1	AL-Huweizah	2-3.5	20-28	70-79	2,400-2,900
2	AL-Qurna	1.8-3	25-30	75-83	2,600-3,000
3	Abu-Zirig	2.5-4.6	17-20	80-95	1,800-2,500
4	AL Hammar	2.6-3.4	25-30	100-125	3,500-4,000

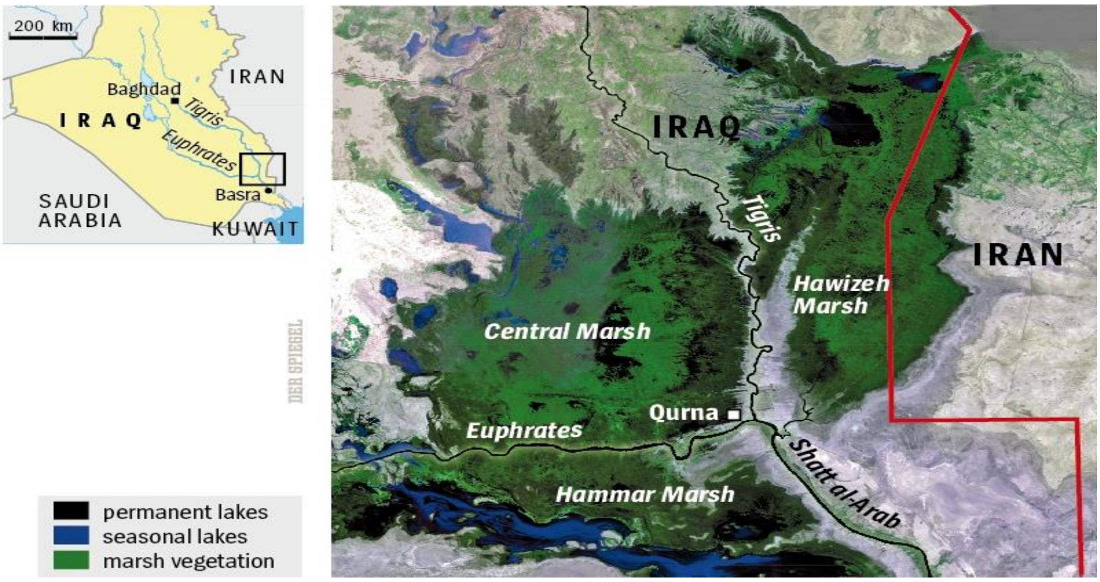

Fig. 2. Marshlands of Southeastern Iraq.

Methods

This study is very necessary for monitoring and assessing the water quality in marshlands south of Iraq. The benefits of this study are restoration, rehabilitation of the marshlands as well as the environmental and water quality improving in the marshes southern Iraq. This research work mainly images of Landsat-7 (TM and ETM) data by path 166 and row 38, 39 were selected to identify the spatial changes in the marsh zones and to support the catchment delineation marshes. These are major set of images used in time series, which were extended within the modeling period of the marsh. The geographical classification of these images depending on bands from 1-7 band as well as the spectral range from (0.45 µm-2.35 µm). These sets are used for both the qualitative and quantitative calibration of the water quality models of the marsh. This study is depending on the differential equation algorithm and integrating between RMA-2 model and RMA-4 model with remote sensing techniques and geographic information system to compute water surface elevations and horizontal velocity of the water as well as for monitoring and assessing water quality parameters such as (TSS, TDS, Salinity) in the study area. The flowchart of the methodology such as explained below (Fig. 3).

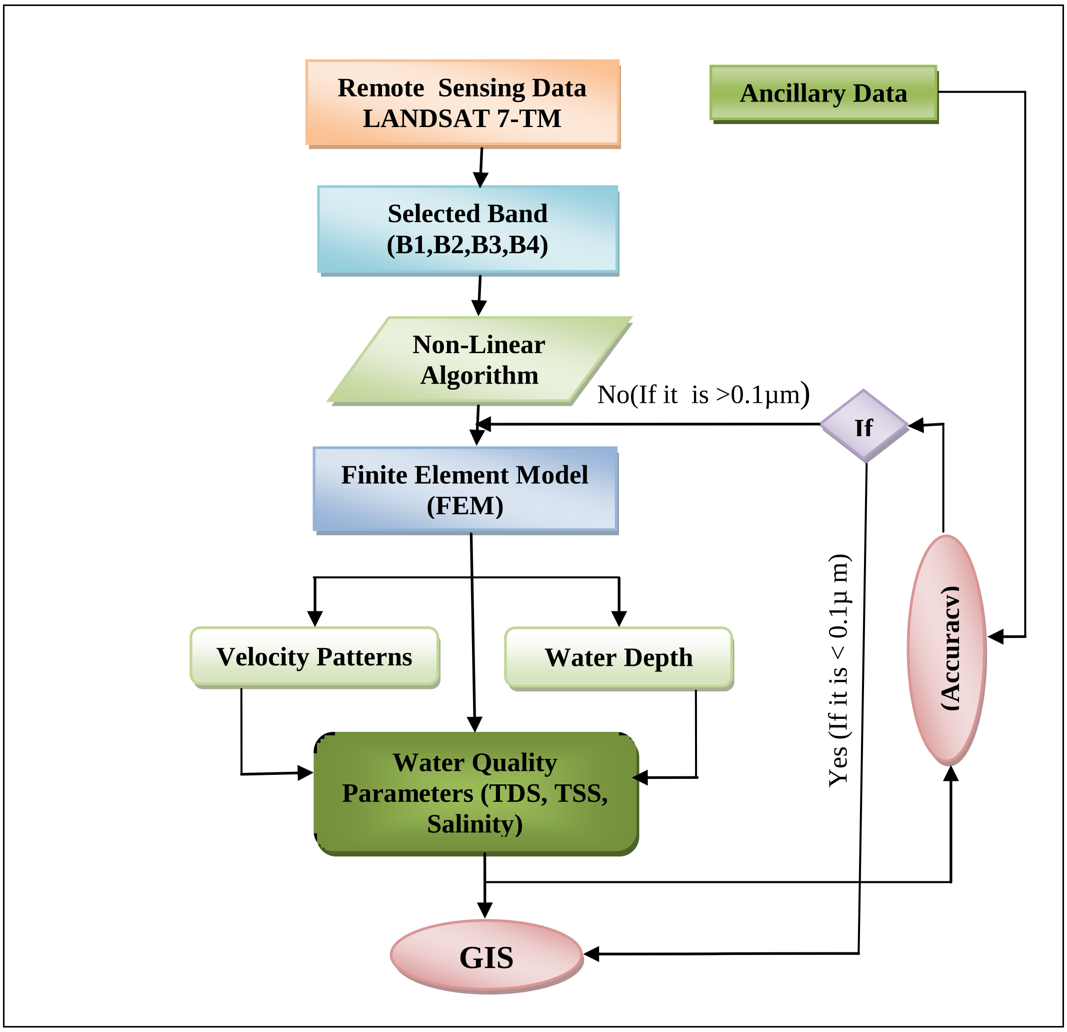

Fig. 3. Flowchart for the methodology.

Data Collection and Model

Data collections are required, such as a hydrological data inflow and outflow of all marshes and topographical data as the marsh boundaries, area, surface water elevation, depth water, geographical location of sources, pollution stations and geographical location for sampling stations as well as the satellite images such as Landsat-7 (TM, ETM) that resolution 30 m^2 and seven bands. The finite element model (FEM) is the dominant discretization technique in structural mechanics. The basic concept in the physical interpretation of the FEM is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry called finite elements or elements for short. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions, as a set of nodal points.

The response of the mathematical model is then considered to be approximated by that of the discrete model obtained by connecting or assembling the collection of all elements. The disconnection-assembly concept occurs naturally when examining many artificial and natural systems. It can be applied to a fluid as the water to determine water depth and water flow analysis as well as for assessing and monitoring water quality when integrate with remote sensing techniques and geographic information system applications.

Finite Element Numerical Model

In mathematics, the finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for differential equations. It uses variation methods (the calculus of variations) to minimize an error function and produce a stable solution. Analogous to the idea that connecting many tiny straight lines can approximate a larger circle, FEM encompasses all the methods for connecting many simple element equations over many small subdomains, named finite elements, to approximate a more complex equation over a larger domain.

Mesh Module

The two dimensional mesh module is used to manipulate two dimensional unstructured grids referred to as a mesh inside of surface-water modeling system (SMS). A mesh consists of nodes that are grouped together to form elements. These nodes and elements define the computational domain of the numerical model. The mesh may assign additional information to the nodes and elements such as material values assigned to elements and boundary conditions assigned to nodes. In general, this additional information is used as input data for the numerical model. Used to create, edit and visualize mesh data. Also referred to as unstructured grids or finite element meshes. Meshes defined by nodes and elements. This study is depending on develop differential equations algorithm which such as shown below that led to develop both RMA-2 model and RMA-4 model. These models will integrated with remote sensing techniques and geographic information system to compute water surface elevations and horizontal velocity of water as well as for monitoring and assessment water quality parameters such as (TSS, TDS, Salinity) in the study area. The differential equations algorithm as explained below.

The continuity equation in unsteady flow problems may be written as.

$$\frac{\partial h}{\partial t} + h \quad \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \quad + u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} = 0 \qquad (1)$$

While the momentum equations in x and y directions are:

$$h\frac{\partial u}{\partial t} + hu\frac{\partial u}{\partial x} + hv\frac{\partial u}{\partial y} - \frac{h}{\rho}\left[\mathrm{E}_{xx}\frac{\partial^2 u}{\partial x^2} + \mathrm{E}_{xy}\frac{\partial^2 u}{\partial y^2}\right] + gh\left[\frac{\partial a}{\partial x} + \frac{\partial h}{\partial x}\right] + \frac{gun^2}{\left(1.486h^{1/6}\right)^2}\left(u^2 + v^2\right)^{1/2} - \xi V_a^2 \cos\psi - 2h\, v\omega\, \mathrm{Sin}\, \Phi = 0 \qquad (2)$$

$$h\frac{\partial v}{\partial t} + hu\frac{\partial v}{\partial x} + hv\frac{\partial v}{\partial y} - \frac{h}{\rho}\left[\mathrm{E}_{yx}\frac{\partial^2 v}{\partial x^2} + \mathrm{E}_{yy}\frac{\partial^2 v}{\partial y^2}\right] + gh\left[\frac{\partial a}{\partial y} + \frac{\partial h}{\partial y}\right] + \frac{gvn^2}{\left(1.486h^{1/6}\right)^2}\left(u^2 + v^2\right)^{1/2} - \xi V_a^2 \sin\psi - 2hu\omega\, \mathrm{Sin}\, \Phi = 0 \qquad (3)$$

Equations (Eq.1, Eq. 2, Eq. 3) are solved by the finite element method using the Galerkin Method of weighted residuals. While the generalized computer program solves the depth-integrated equations of the transport and mixing process. The form of the depth averaged transport equation such as button.

$$h\left[\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} - \frac{\partial}{\partial x} D_x \frac{\partial c}{\partial x} - \frac{\partial}{\partial y} D_y \frac{\partial c}{\partial y} - \sigma + kc + \frac{R(c)}{h}\right] = 0 \qquad (4)$$

Results and Discussion

In order to fulfill the overall aim and objectives of the study, the results and analyses will achieve based on the pre-processing and processing of the input datasets. The obtaining results as the image classification of central marshes in 1973 (Fig. 4) and the change detection of the study area in 1994, 2005 and 2014 (Fig. 5). Topographical classification ratios of central marshes in (1994, 2005, 2014) as well as the ratios by percentage % (Fig. 6, Fig. 7). Moreover water depth, velocity patterns, contours lines and geographical location sampling (Fig. 8) as well as water quality parameter concentrations and distribution for (TDS, TSS, Salinity) in the central marshes (Fig. 9, Fig. 10).

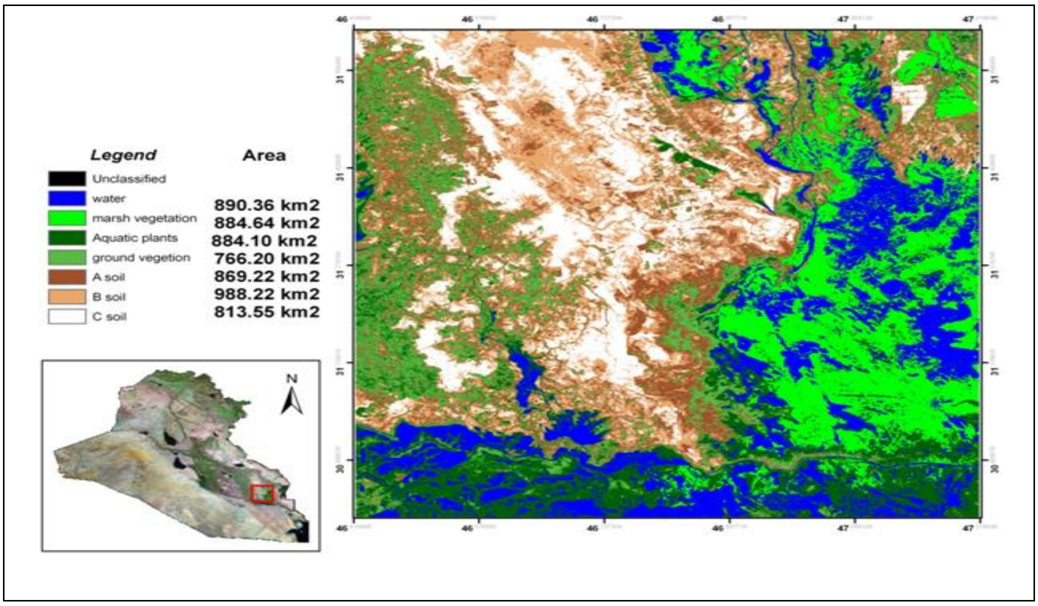

Fig. 4. Image classification for the central marshes in1973.

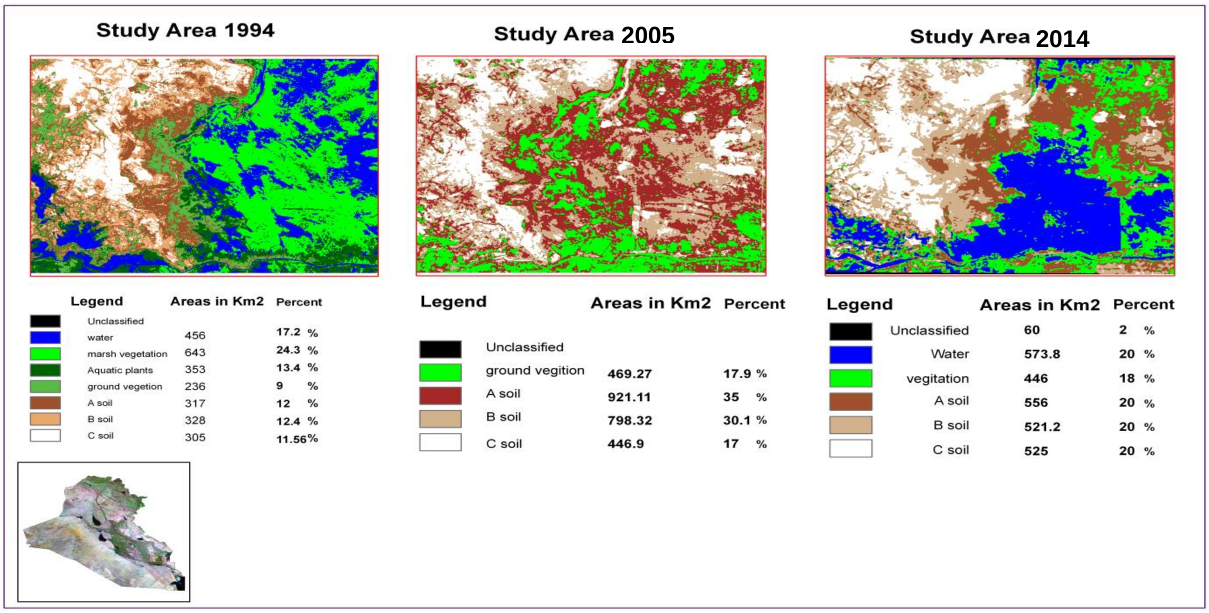

Fig. 5. Change detection of central marshes through satellite images in (1994, 2005&2014).

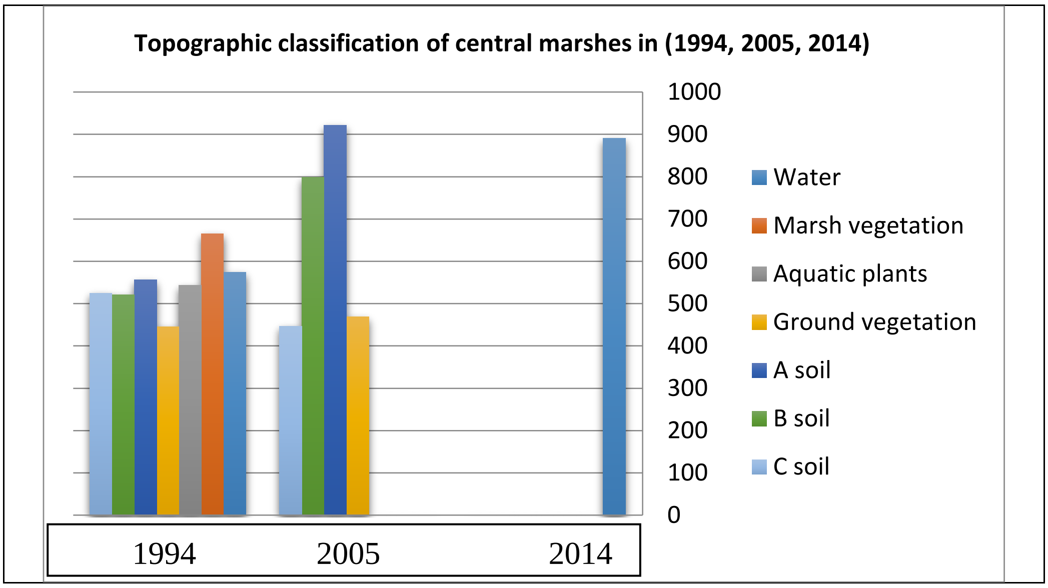

Fig. 6. Topographic classification of central marshes in (1994, 2005, 2014).

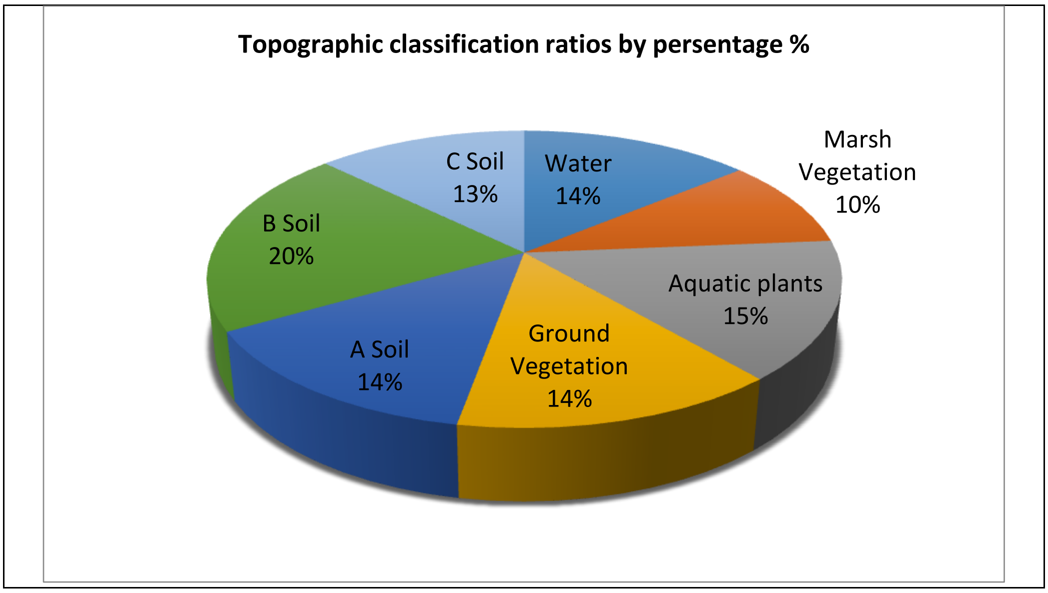

Fig. 7. Topographic classification ratios of central marshes by percentage %.

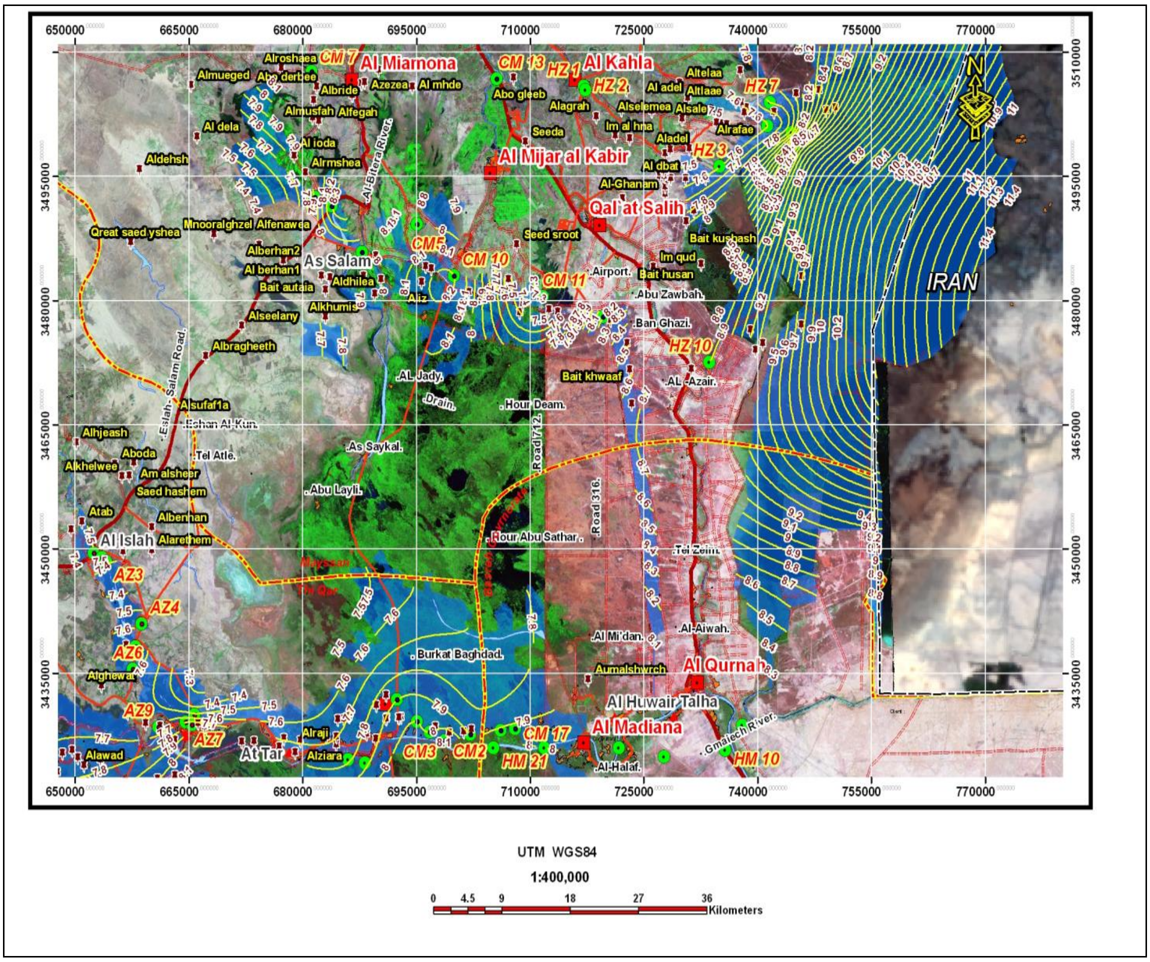

Fig 8. Geographic location sampling from satellite image of central marshes in 2014.

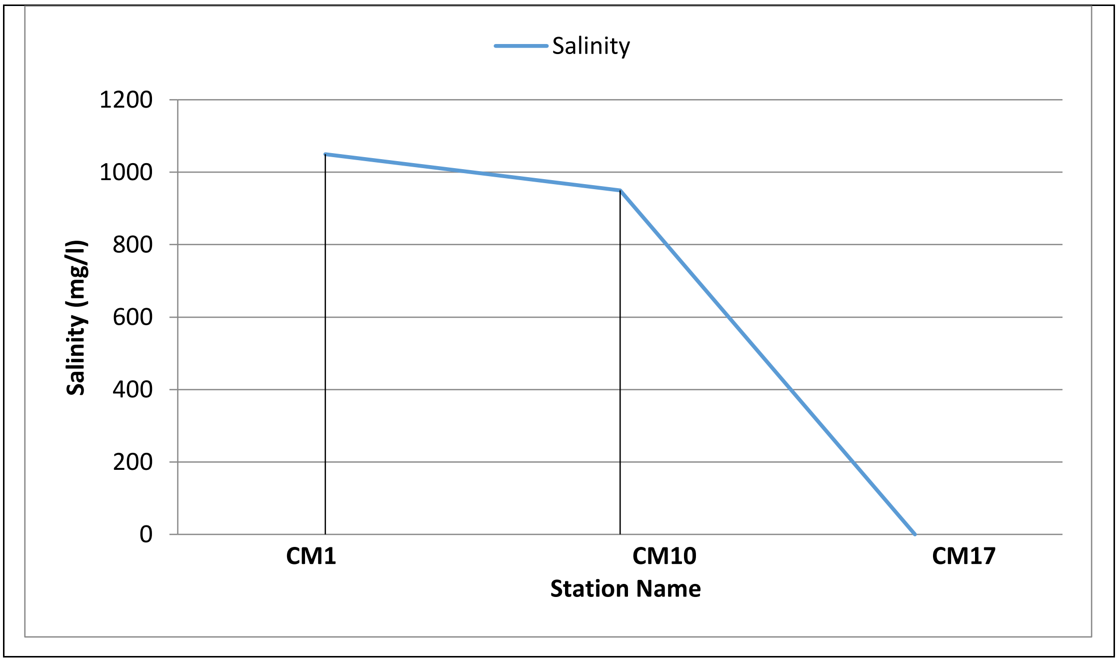

Fig 9. Salinity concentrations of samples stations taken from Central marshes.

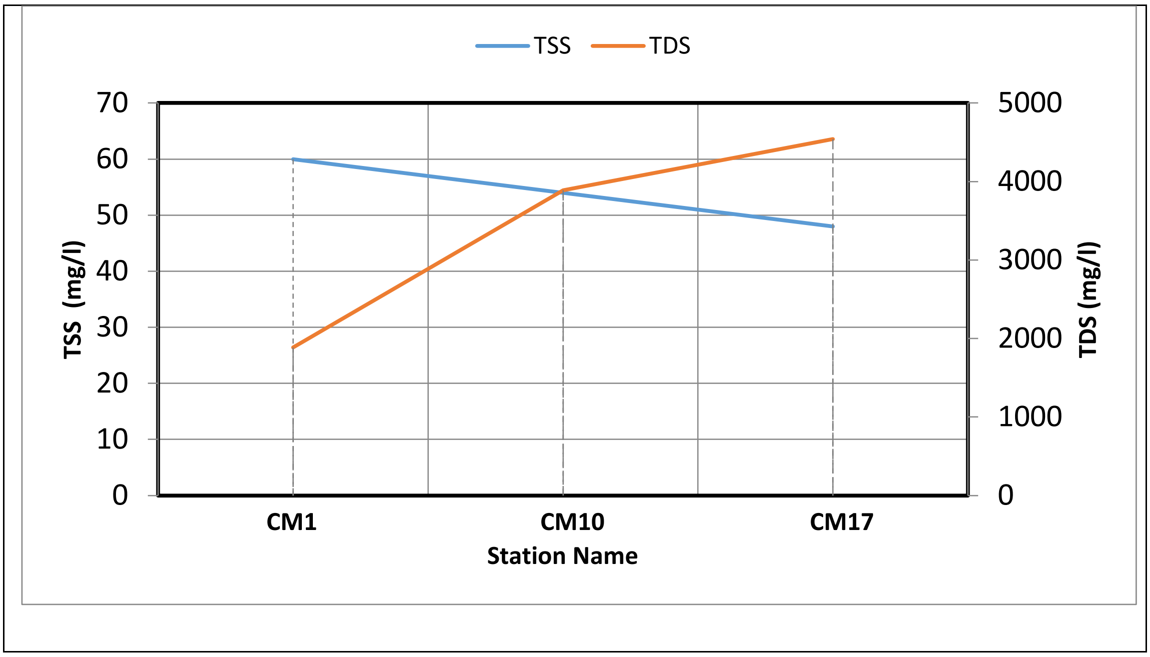

Fig 10. (TDS & TSS) concentrations of samples stations taken from Central marshes.

Conclusion

This study demonstrated method for water quality distribution in Iraq depending on the integration between Landsat satellite data and finite model. The study shows that the water quality parameters as salinity was increased exponentially with station CM4 and decrease with stations CM6. However TSS concentrations were increased with stations CM4-CM5 and decrease with station CM6 but TDS concentrations were increased with stations CM6 and decrease with station CM4. This can prove that there are exponentially relationships between the geographical location of sampling and water quality concentrations of the central marsh zone. The heavy densities of water quality parameter concentrations of central marsh are existed with area or stations of low water level and storage. The central marshes have the lowest elevations, as compared with other marshes, therefore they have the shallowest groundwater level and highest salt content.The barren lands increased between the years 2005-2014, and thus the marsh areas decreased. The clear water marshes decreased about 0.3% from there original areas, between 1994 and 2005. The natural vegetation cover decreased, within the marsh areas. After rehabilitation in year 2005, the areas of the central marsh begin to increase about 24%.

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