

Design of Irrigation Management System in Gezira Scheme Using Geographic Information System

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Abstract— Gezira scheme, ultimately becomes the largest centrally-managed irrigation project in the world. This paper presented a design to provide intelligent system used for managing irrigation in Gezira scheme. The system solves the problem of crops thirsty and water loss. The paper aims to monitor the flow of water in the channels, which ensures the arrival of accurate water for all areas of the project. The Geographic information system (GIS) data analysis helps to get knowledge of what area is actually has the potential for growing. The used image obtained from LANDSAT8 satellite and with the aid of ARC-GIS application for the Normalized Difference Vegetation Index NDVI was calculated. The obtained results revealed that the region of red color, which has NDVI between (-0.2 - 0) represents non-growing area, the region of yellow color which has NDVI between (0 - 0.3) represents and the region of green color, which has NDVI between (0.3 - 0.55) represents normal irrigated area. The results of the NDVI have proven that the system can be used successfully. A hardware circuit was designed to enable the use of the NDVI that results in the opening or closing of the flow of water. Also, the results show the use of the global positioning system (GPS) system in the field of study that gives the local or global coordinates according to the coordinate system used in the study.

Index Terms— Control System; Gezira Scheme; Irrigation; NDVI; X-bee.

I. INTRODUCTION

In the past, economists had expected that Sudan will be the bread-basket of the world in the future. However, due to the deterioration of agricultural systems, especially the Gezira scheme, Sudan has become worse economically. In fact, there has been a bread crisis over the country. Since its establishment in 1925, the Gezira Scheme [1] has become the backend of the Sudan economy. Managed by the government of Sudan, it is the largest centrally-managed irrigation project in the region [2]. The Gezira (which means "island") is particularly suitable for irrigation system because the water naturally flows from the Blue Nile to the growing area through the irrigation canals by gravity [3]. There are some challenges stand up against the succession of the irrigation operation in the project. The biggest challenge faced by this operation is controlling the quantity of water in the irrigation channels and preventing the sinking of crops or thirst. In summer 2018, approximately 20 percent of the crops were damaged due the failure of the irrigation operation. The expected major problem Sudan will face is the water shortage due to the Grand Ethiopian Renaissance Dam. In this case, it necessary to use technology to find a radical solution to this problem, specifically the best way to control the rate of water

flow and quantity of water in agricultural channels through the geographical information systems [GIS]. The failure in Gezira scheme during the recent years is due to poor management leading to losing large fertile agriculture areas [4]. The problem of managing irrigation and controlling the types of crop for plantation can be solved by GIS. In irrigation systems, weather plays an imperative role in decision making, implementing and forecasting. Calculation of evaporation is the key to determine the suitable water requirement for the type of crops. This calculation depends on several parameters such as temperature, humidity, precipitation, and solar radiation [5]. In this paper all these factors have been considered, in addition to the algorithm for the design of the remote opening and closing water pumps, based on the results of GIS system.

II. RELATED WORKS

There are a lot of implementation efforts published in different topics of Irrigation management system using GIS. All these papers are different because most of these papers only provide a monitoring of irrigation operation by GIS, but do not provide control fetcher. The analysis and simulation adopted by El-Hallaq et al. [6] play an important role in the sustainable development process. Bansal et al. [7] introduced a new mechanism to protect GIS data carrying confidential and sensitive data for military and army purposes by combining two of the cryptography algorithms. Shi et al. [8] compared two classification systems for the development of urban area land use and land cover using Landsat ETM+ imagery. Azar et al. [9] reviewed a customization of ArcGIS as irrigation management tool. Taking into consideration the big data with its vast volume and complexity, Huang et al. [10] developed a system used by all professions and trades.

Remote sensing, as one of the sources for big data, is generating earth-observation data. The significance of the proposed work in this paper is that it focuses on a design system that aims to monitor and control the flow of water in the channels, which ensures the arrival of sufficient water for healthy crop growing in all areas of the project. It also provides a monitoring system specific to the types of crop grown in the project. A survey of related works in this field is shown in Table 1.

Table 1
Summary of Related Works

Author	Year	Description
M. A. El-Hallaq et al. [6]	2019	Urban development through Smart City: using GIS, unlike our proposed system which specified for controlling and monitoring irrigation process.
Bansal et al. [7]	2018	Three-Level GIS Data Security.
Y. Shi et al. [8]	2019	This paper used GIS to analysis the irrigation water.
R. Azar et al. [9]	2016	Crop classification performance using satellite data
Huang et al. [10]	2018	Remote sensing for big data.
J. Chen et al. [11]	2019	A GIS-Based Framework to Identify Opportunities to Use Surface Water to Offset Groundwater Withdrawals.
A. Begue et al. [12]	2018	Remote sensing and cropping practices.
S. Acharya et al. [13]	2014	Use of Geographic Information Systems in irrigation management.

III. METHODOLOGY

The main concept of this paper is to design a system that can be used to analyze raster data with a resolution of 30 meters received from the satellite using the ArcGIS application. The fieldwork area in this paper is shown in Figure 1. GPS system was used to accurately determine the coordinates of the study area as a whole and the places of experimentation and determination of the latitude and longitude of the display circuits. Figure 2 and 3 show the irrigation and thirsty area respectively.

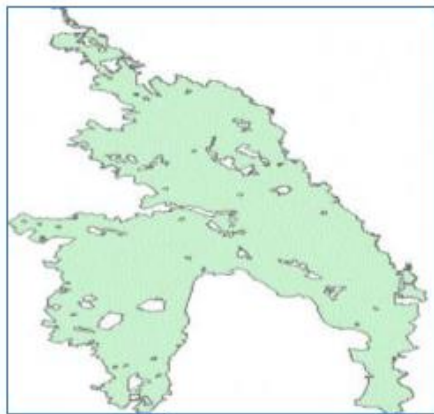


Figure 1: Gezira scheme



Figure 2: Irrigated area

The obtained information indicate the present state of plant and the amount of water and the control of hardware circuit, which has the ability to open or close the water from Gezira Scheme. Figure 4 shows the general algorithm of the system.



Figure 3: Thirsty problem

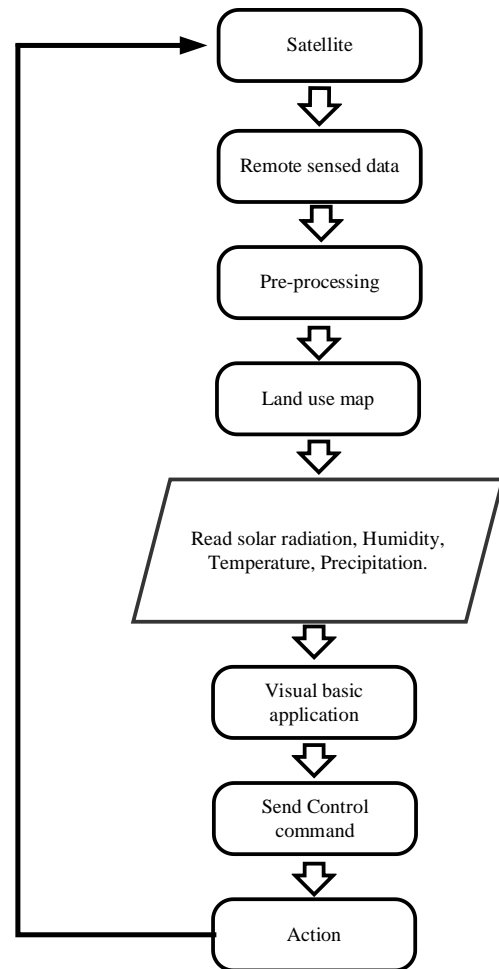


Figure 4: Operation algorithm

IV. NDVI CALCULATION

The Normalized Difference Vegetation Index (NDVI) is a quantitative index of greenness ranging from 0 to 1, where 0 represents minimal or no greenness and 1 represents maximum greenness. Figure 5 shows the method of how NDVI Calculation can be obtained.

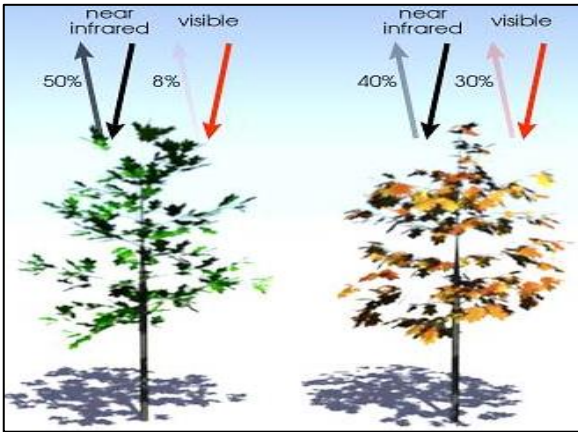


Figure 5: NDVI method source: adapted from [14]

The NDVI is calculated from these individual measurements as follows:

$$NDVI = ((IR - R) / (IR + R)) \quad (1)$$

where: *NDVI* = Normalized difference vegetation index
IR = Pixel values from the infrared band
R = Pixel values from the red band

The final analysis was done by a designed program using the VISUAL BASIC .NET programming language and then definitively identified the areas affected by thirst and sinking.

V. CONTROL SYSTEM

After the calculation of NDVI value and classification of areas using GIS system, the next step is sending this value to the visual basic application (VB-APP), VB-APP which checks this value: If the value < 0, it refers to a not growing area, therefore the system will return to check a new value; if the value > 0 and < 0.3, it refers to thirsty area, therefore the system opens the motor; if the value > 0.3 and < 0.55, it indicates to normal irrigated area and the system returns to check a new value. Figure 6 shows the flowchart of the control system unit.

Figure 7 illustrates the configuration of the circuit, which consists of two pumps, a driver and a serial port. The controller in the simulation circuit is based on an arduino board. The proposed circuit in this paper is aimed to perform the controlling operation of the flowing water in the project. It is either to open or to close the water from the growing area. For more facility application, it has been designed using visual basic.NET, Figure 8 shows a screen shot from the designed application.

The design used the obtained results of NDVI analysis to feed the hardware, which opens or closes the pumps, whenever it is needed.

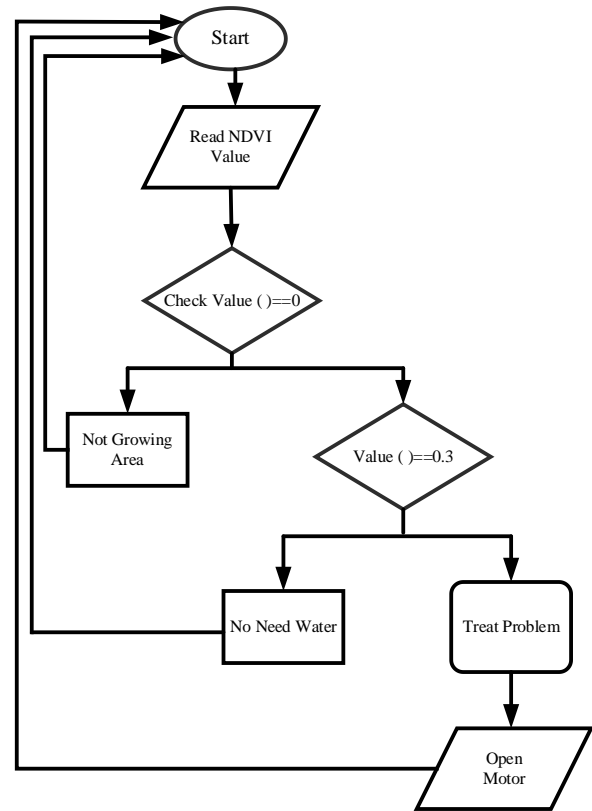


Figure 6: Control unit algorithm

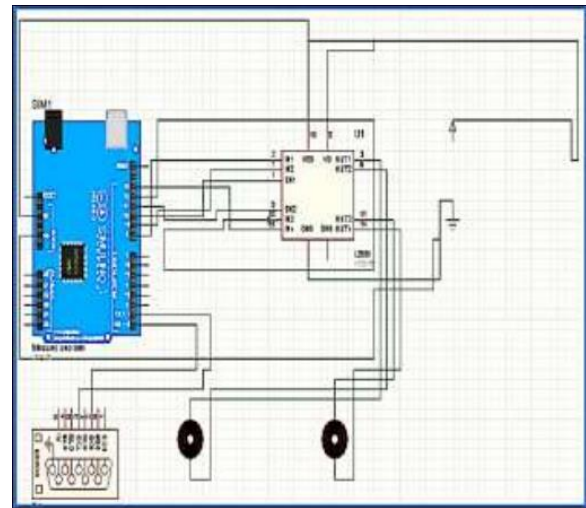


Figure 7: Circuit scheme

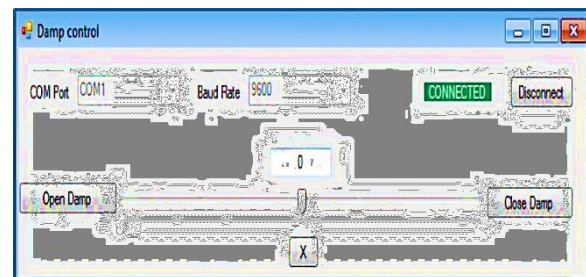


Figure 8: Application page

VI. RESULTS AND DISCUSSIONS

The steps of the NDVI calculation are shown in Figure 9 to Figure 11. Each layer refers to a dataset that is stored in a geo-

database, coverage, shape file, raster, and so on. It is easy to add layers to a map; It can be done by selecting a dataset and dragging it from the catalog or searching a window onto your map or adding a dataset using the add data button, as shown in Figure 9.

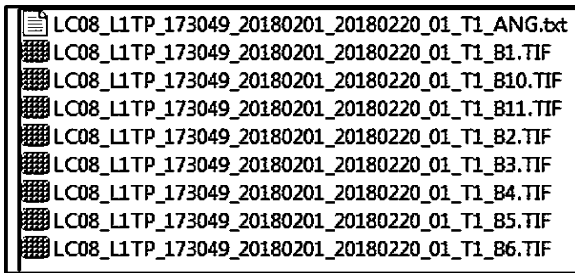


Figure 9: Select layers

A shape file is a simple, no topological format for storing the geometric location, and it contains attribute information of geographic features. Geographic features in a shape file can be represented by points, lines, or polygons (areas), as shown in Figure 10. Figure 11 shows the calculated area from the classified image and the statistics describing the values in numeric columns.

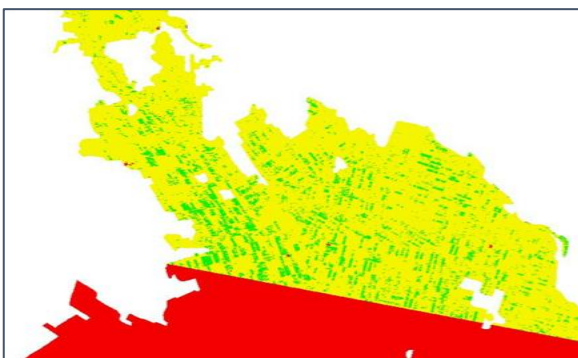


Figure 10: Classified area

OID	Value	Count	km
0	0	3	90
1	1	124518	37355600
2	2	133211	39963400
3	3	161991	4859730

Figure 11: Area calculations

After the process of NDVI calculation of the satellite image, statistics for the items that include them were extracted, and then the percentage occupied by each cover pattern of the total area of 419721Cells equal 2998 acre was identified. Therefore, the results solved the problem of monitoring the types of crop in the project (know what is actually grown from the area).

$$A = RR * Cell \tag{2}$$

where: A = Area in meter
RR = Raster Resolution

Cell = Element or grid

The final calculated results of the growing area obtained from the NDVI analysis were summarized in Table 2.

Table 2
Growing Area

	Cells	Area (meter)	Area (acre)
1	124518	3735540	890
2	133212	3996360	951
3	161991	4859730	1157
Total	419721	12591630	2998

The overall result explained how GIS can be used to determine the sinking and thirsty area; therefore, it can be used to control the irrigation operation. It also shows how GIS can be easily used to monitor the types of crop in the project.

VII. CONCLUSION

This paper showed an advance design of monitoring and controlling irrigation in Gezira scheme. The system used GPS and GIS technologies to detect thirst and sinking crops. The obtained results show that the system has the ability to produce accurate and reliable results. The results of the NDVI have proven that the system can be used successfully. The overall results of the study demonstrate the ability of using geographic information systems and remote sensing algorithm of vegetation. It provides accurate maps of the land segments and has the ability to determine the cultivated and uncultivated area. The paper presented a control algorithm for managing the irrigation operation remotely. For future works, this design can be improved by using GSM in the relative control systems because the transmission range is greater and uses non-free accounts in LANDSAT8 to provide the researcher with higher quality images.

ACKNOWLEDGMENT

This works was done under supervision of Al- Gezira Technical Collage.

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