

Evaluation of Total Demand For Al-Hussainiyah Irrigation Project Using Geomatics Techniques

Dr. Abdul Razzak T. Ziboon 

Building and Construction Engineering Department, University of Technology/ Baghdad

Dr. Mahmoud S. Mahdi

Building and Construction Engineering Department, University of Technology/ Baghdad

Hanan Kadhum

Building and Construction Engineering Department, University of Technology/ Baghdad

Email: 41100@uotechnology.edu.iq or linoxer@Gmail.com

Received on:16/9/2014 & Accepted on:8/10/2015

ABSTRACT

In this paper, the crop water requirement was calculated using two methods; the first method is FAO-56-Penman Monteith. While the second method, is the Penman Monteith utilizing satellite image data where the Landsat 5 TM image is used in this method. The estimated ET_c using these two methods was of equal value, 5.20 mm/sec. This verifies the use of this satellite image for estimation of ET_c . The agricultural situation and water demand of each canal and the corresponding cultivated area were evaluated. This evaluation shows that Al-Hussainiyah Canal has the highest value of discharge ($12.43 \text{ m}^3/\text{sec}$) with maximum cultivated area (89.82 km^2). The Al-ajmea Canal has the lowest discharge rate of ($0.25 \text{ m}^3/\text{sec}$), with minimum cultivated area of (0.39 km^2). These canals operate under half of their design discharge and the cultivated area for this project distributed mainly along the main canals. Evaluation of the water use efficiency (WUE) of the project shows that the maximum value of the estimated WUE was at Al-kamalea canal $7.9 \text{ km}^2/\text{m}^3/\text{sec}$. While the minimum value was at Al-ajmea canal $1.6 \text{ km}^2/\text{m}^3/\text{sec}$. The average WUE for the area of study was $7.2 \text{ km}^2/\text{m}^3/\text{sec}$, which is equal to the WUE of Al-Huassainiyah Canal. It has been proven that the Landsat 5 TM image can be effectively used in monitoring irrigation network, especially when considering large areas. It can be used for estimating and evaluating the water consumption and the water use efficiency of the irrigation projects in Iraq.

Keywords: Al-Hussainiyah, evaluation, estimation, remote sensing.

INTRODUCTION

Irrigation policy makers and managers need information on the irrigation performance and productivity of water at various scales to devise appropriate water management strategies. This is not easy to obtain by using the field survey as many irrigation projects cover hundreds and sometimes thousands of square kilometers. Therefore, geomatics techniques especially satellite data can be used to monitor and evaluate the performance of the irrigation projects and water use efficiency and accordingly perform and develop an efficient management plans. In most of the irrigation projects there is no integrated evaluation for the performance of these projects and for the matching between the supplied discharges, the real demand

for the cultivated lands and that specified in the agricultural plans and cropping patterns of these projects. Al-Hussainiyah Irrigation Project which is located in Karbala governorate in Iraq country is one of the irrigation projects that suffer from such problem. In spite of there is no integrated evaluation for the performance of this project, the extend in project area and construction of new irrigation networks continued depending on an old studies and plans, some times of 30 years old. This study aims to evaluate the agricultural situation, the water consumptions and demands and coincidence of the irrigation network for these demands in Al-Hussainiyah Irrigation Project using geomatics techniques.

Methodology

This study was achieved according to the following approaches:

Theoretical Approach: includes reviewing the related theories, equation and techniques.

Data Collection Approach: includes Satellite Data (Landsat 5 TM image, Sept. 3, 2007), Climatic data, Present state of agriculture and Hydrological Data (the data and information that concerns the consumption, losses, efficiency and discharges).

Utilize Software: Software packages that used in this study were: Microsoft Excel 2007 for statistical analysis, ERDAS Imagine 2013 for image processing, ENVI v. 4.8. for image conversion, Arc GIS 9.3 for GIS data analysis and CROPWAT 8.0 software for estimating the water consumption.

Theoretical Framework

The irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation. The crop evapotranspiration denoted as ET_c, and can be calculated from reference evapotranspiration (ET_o) and the crop coefficient (K_c), by using equation (1) [2].

$$ET_c = ET_o \times K_c \dots\dots (1)$$

Where: ET_c is the crop evapotranspiration (mm d⁻¹), ET_o is the reference evapotranspiration (mm d⁻¹) and K_c is the crop coefficient (dimensionless).

ET_o is determined using various methods and empirical equations. One of the most widely used methods is the Penman Monteith -FAO-56 Model, equation (2), [21].

$$\left[\frac{\Delta(Rn - G) + \frac{0.6108 U_2 (e_s - e_a)}{T + 2.73}}{\gamma(1 + \frac{0.34 T}{273.15})} \right] \dots\dots (2)$$

where: Δ is the slope of the vapor pressure versus temperature curve (kPa/°C), R_n is the net radiation at the crop surface (MJ m⁻² d⁻¹), G is the soil heat flux (MJ m⁻² d⁻¹), γ denotes the psychrometric constant (kPa/°C), T is the air temperature (°C), U₂ is the wind speed measured at 2 m height (m s⁻¹) and (e_s - e_a) is the vapor pressure deficit (kPa), i.e., the difference between saturation vapor pressure, e_s and the actual vapor pressure, e_a.

To make use of the facilities and advantages of the satellite data, The FAO method which adopted satellite data can be used to estimate ET_c, equation (3), [10]. This equation can be applied by using ground- based meteorological data and satellite-

based estimation of the two canopy parameters needed for the calculation, namely the surface albedo and LAI [7].

$$-\left[\frac{\Delta(\frac{AI}{\gamma(1 - U/0)} + \frac{a(e)}{LAI})^{U/124}}{\dots} \right] \dots\dots (3)$$

where: λ is the latent heat of vaporization (MJ kg⁻¹), LAI is the leaf area index (unit less), C_p is air specific heat (MJ kg⁻¹) and ρ_a is air density (kg.m⁻³).

Image Pre-processing

Pre-processing aims to prepare satellite images for further processing without increasing images information content and that completed with convert Digital Number to Radiance and then Radiance to Reflectance which are a prerequisite for estimate albedo, layer stack and subset data. Thus, Parameters are calculated for each pixel using remotely sensed data. Digital image processing includes Layer Stack which is useful for placing layers one on top of the other [8], Image Subset which is cut out a subset of the larger image to simplify analysis and focus on the portion of the scene that represent the area of interest [26] and Conversion Digital Number to Reflectance where the satellite images produced as digital numbers, each spot viewed on the Earth’s surface as a digital number (DN) for each spectral band. The exact range of DN that a sensor utilizes depends on its radiometric resolution. Using the data image as reflectance form is efficient more than using DN form. Equation (4) can be used to convert the DN to radiance [8], Chander, 2009 and [11]:

$$\left(\frac{\dots}{\dots} \right) (Q \dots) \dots\dots (4)$$

where: L_λ is spectral radiance at the sensor's aperture [W/(m²srμm)], Q_{cal} is quantized calibrated pixel value [DN], Q_{calmin} is minimum quantized calibrated pixel value corresponding to L_{MIN_λ} [DN], Q_{calmax} is maximum quantized calibrated pixel value corresponding to L_{MAX_λ} [DN], L_{MAX_λ} is Spectral at-sensor radiance that is scaled to Q_{calmax} [W/(m²srμm)] and L_{MIN_λ} is Spectral at- sensor radiance that is scaled to Q_{calmin} [W/(m²srμm)]. Equation (5) [3] and [11] can be used to convert the radiance to reflectance.

$$\dots\dots\dots (5)$$

where: ρ_λ is planetary reflectance or Top-Of-Atmosphere (TOA) reflectance [unit less], π is mathematical constant equal to 3.14159 [unit less], L_λ is spectral radiance at the sensor's aperture [W/(m²srμm)], D is earth- sun distance [astronomical units], $ESUN_\lambda$ is mean exoatmospheric solar irradiance [W/(m²μm)] and θ_s is solar zenith angle [degrees].

Classification Algorithms

Classification algorithms are the most common techniques for interpreting satellite multispectral data in land resources monitoring. Almost every software package for image analysis includes several classification methods with different approaches [6]. Although unsupervised and supervised classification is largely used for mapping land use attributes, they are not straightforwardly applicable for the purpose of this study.

Knowledge-Based Classification can be used as an alternative approach to manual image interpretation. It is also known as knowledge Based Expert System (KBES) [9]. The use of remote sensing analysis techniques with the Landsat data in order to discriminate plantation, when comparing the results with the typical classification, the results indicate that higher classification accuracy can be obtained than other classification [25].

Vegetation Index (VI)

VI is the land-cover in term of plant biomass. The vegetation may be of permanent type i.e. lasting or standing for months and years, such as forests; others may be temporary grown for few months only, such as seasonal crops [4]. Vegetation Indices (VIs) are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation.

Ratio Vegetation Index (RVI) Is the simplest vegetation index, it is the ratio of near infrared band and red band. It indicates the amount of vegetation, in the resultant RVI image, high values, such as more than 20, indicates dense vegetation and low values, which are around the value of 1, indicates soil, ice and water [1]. Also, $RVI < 1 =$ Water, $2 > RVI > 1 =$ Bare soil or soil with low coverage of leaf area, $RVI > 2:$ Green vegetation. The higher the RVI, the more is the green vegetation coverage. RVI saturated nearly at the value 5, it expressed as shown in equation (6) [21]:

$$\text{..... (6)}$$

Where: ρ_{red} is red reflected radiant flux [unit less] and ρ_{nir} is near-infrared reflected radiant flux [unit less].

Leaf Area Index (LAI) is the amount of leaves area per unit land surface area. LAI estimation is based on a semi-empirical reflectance model that calculates LAI of a green canopy based on the Weighted Difference Vegetation Index (WDVI) and the inverse of an exponential function [5]. For the calculation of LAI, an empirical exponential equation for annual crops as shown in equation (7) [19]:

$$\text{..... (7)}$$

Where: WDVI is the weighted difference vegetation index.

WDVI is as efficient as most of the slope-based VIs. The effect of weighting the red band with the slope of the soil line is maximization of the vegetation signal in the near-infrared band and minimization of the effect of soil brightness as shown in equation (8) [20].

$$\text{..... (8)}$$

Where: ρ_{nir} is reflectance of near infrared band, ρ_r is reflectance of visible red band and γ is the slope of soil line.

Soil Line represents the relationship between the red and the near-infrared soil line reflectances. It is obtained through linear regression of the near-infrared band against

the red band, values falling near the soil line are assumed to be soil, while those far away are assumed to be vegetation [23], as shown in equation (9).

$$Nir(\text{soil}) = a \text{ red}(\text{soil}) + b \quad \dots\dots\dots (9)$$

Where: Nir (soil) is soil reflectance in the near-infrared band, red (soil) is soil reflectance in the red band, a and b are parameters of the soil line (estimated statistically).

Albedo is the ratio of the total amount of electromagnetic energy reflected by a surface to the amount of energy incident upon it. Liang's equation, equation (10), can be used to estimate the elbedo (Liang, 2000). Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 5 Thematic Mapper (TM) have the same multispectral reflective wavebands with the similar spectral coverage, this equation is suitable for converting land surface reflectance to albedos, (Liang, 2000; [13]. Thus, the albedo calculation is a Landsat image that has been converted from digital numbers to (TOA) reflectance [24].

$$\dots (10)$$

where: ρ represents albedo and r_i is the reflectance of the specific spectral band i ($i=1,2,3,4,5,6$ and 7).

Study Area

Al-Hussainiyah Irrigation Project is located in Karbala governorate in the central region of Iraq and extends between latitudes N 32° 36' to 32° 48' and longitudes E 43° 55' to 44° 17', Figure (1).

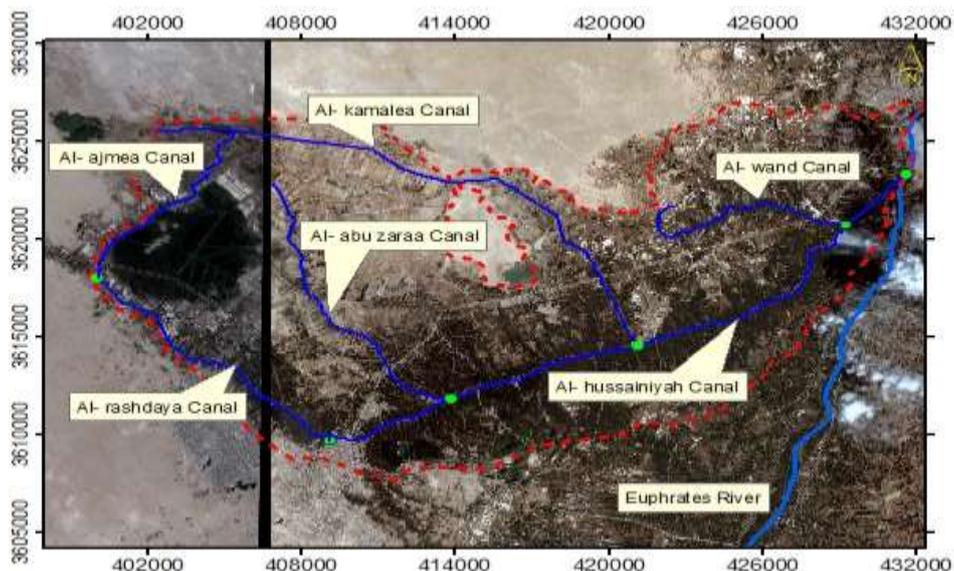


Figure (1): Layout of Al-Hussainiyah irrigation project.

Climatic Parameters

The main climatic parameters that affect crop water requirements include air temperature, humidity, wind speed, sun shine duration, evaporation and rainfall. Data

from Karbala weather station have been gathered for the main climatic parameters [17]. A summary of this data was listed in Table (1).

Table (1): Summary of the average climatic parameters [17].

Climatic parameter	Month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean air temp. (°C)	10.3	13.0	17.0	23.3	28.9	33.2	36.4	35.7	32.1	24.8	16.8	11.6
Mean rainfall (mm),	21.5	14.6	15.8	13.4	4.1	0.1	0.0	0.0	0.3	3.6	10.8	17.3
Mean max air temp. (°C)	16.0	19.1	23.8	30.8	37.0	41.7	44.1	43.9	40.3	33.4	23.8	17.7
Mean min air temp. (°C)	4.5	6.9	10.1	15.7	20.8	24.6	28.7	27.6	24.0	16.2	9.8	5.4
Mean monthly evaporation	63.7	96.8	175.	253.	348.	437.	473.	427.	320.	215.	107.	66.4
Mean relative humidity (%)	73.5	59.6	51.4	42.3	34.1	28.3	29.1	31.2	35.5	45.2	61.4	71.8
Mean sun shine duration	6.2	7.0	7.9	8.4	9.3	11.2	11.4	11.0	9.9	8.1	6.9	6.0
Mean wind speed at 2 m height (m/sec)	1.7	2.0	2.3	2.4	2.4	3.1	3.2	2.6	1.9	1.6	1.4	1.5

Crop Pattern

The study area is characterized three cropping seasons, winter, summer, and perennial. The main winter crops are wheat, barley, and winter vegetable. Maize and summer vegetables are the dominant summer crops, while the orchards, palms and alfalfa are the dominated perennial crops [14]. The crops that can be grown in the Al-Hussainiyah Irrigation Project together with their planting and harvesting dates are as listed in Table (2) [16].

Table (2): Crops patterns, dates of planting and harvesting [16]

Crops	Area (donum) 2007	Planting date	Harvesting date
Wheat	5025	16/11	30/4
Barley	2385	16/11	20/4
Berseem	300	11/10	10/5
Beans for grain	619	1/9	5/3
Winter legumes (fodder)	1040	16/10	15/4
Winter vegetables	16087	16/10	5/4
Maize	4384	11/3	5/7
Cotton	1	1/4	10/9
Sunflower	3	21/3	31/7
Sesame	50	1/5	10/9
Small grain	60	6/4	15/8
Summer vegetables	5369	21/3	30/9
Orchards and palms	79797	Perennial	
Alfalfa	1877	Perennial	

Irrigation Network

Currently, the irrigation network in Al-Hussainiyah Irrigation Project is composed of lined and earthen canals. After 2009 till now, there was a campaign work from Ministry of Water Resources (MoWR) for canals lining in different zones in the project. The main canal in the project is Al-Hussainiyah canal which is about 27 km

long, it is provided with water from Euphrates river by main regulator at Al-Hindiya barrage. The amount of discharge that supplied to the project head for present state for the year 2007 was as listed in Table (3) [18]. In order to estimate the discharge requirements at the head of main canal, it is necessary to have a good evaluation for conveyance losses. The reasonable number is 64%. [15].

Table (3): Available discharge at the head of the project (2007) [18].

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Discharge (m ³ /sec)	10.0	11.4	13.1	15.9	17.6	14.7	20.0	20.0	19.2	12.3	5.0	6.0

Water Consumption Models

Water consumption depends on calculation of evapotranspiration and other losses. Therefore, water consumption can be obtained according to two approaches depending on the method of estimating evapotranspiration by using equation (1) or by using remote sensing method based on the satellite data by using equation (3). The utilized climatic parameters for estimating (ET_o) using equation (2) are as shown in Table (4). Estimation of ET_C using satellite data, equation (3), was carried out using spatial modeler of ERDAS Imagine 2013.

Table (4): Shows climatic data used in this study [17]

Date	T max	T min	RH %	U ₂	Sunshine(hours)
Sept. 3, 2007	46	28.3	31	1.4	11.2

RESULTS

The estimated value of ET_C using Penman Monteith -FAO-56 Model for the day Sept. 3, 2007 was 5.2 mm/day.

The estimated RVI digital image is shown in Figure (2). The maximum value of the estimated RVI is 9.05 while the minimum is zero. The values of WDVI were estimated based on the estimated slope of the soil line, Figure (3) and (4). These values fall in the range from -0.571 to 0.428. The LAI values varied from 4.6993E-0.006 to 0.624689 where vegetation occupied the high values of LAI, Figure (5). The value of Albedo (α) rise whenever the color of the body closest to the whiteness, the estimated values of α , Figure (6), varied from 0.037 to 0.258. The estimated single day ET_C values for the day Sept. 3, 2007 were as shown in Figure (7) which varied from 3.60 to 5.90 mm/day.

The estimated ET_C for the day Sept. 3, 2007 using satellite image and Penman Monteith -FAO-56 Model was 5.2 mm/day for the two methods. The estimated cultivated area for Sept. 3, 2007 is 131.465 km² while the soil area is 228.71 km². The estimated total demand is 18.170 m³/sec, while the measured released discharge at the head regulator of Al-Hussainiyah Canal at this day was 20 m³/sec. The difference between the estimated and measured discharge represents 9.2% of the measured discharge. According to the percentage of the amount of each demand to the total demand, it can be seen that about 60% of this little difference can be attributed to the difficult in specifying exact values of irrigation and conveyance efficiency and the spatial resolution of the utilized satellite image (30m).

The ET_C of each sector were estimated for evaluating the performance of irrigation network use, Figures (8) to (13). A summary of the mean ET_C is listed in Table (5).

Based on the estimated demand of each sector, the Water Use Efficiency (WUE) represented by the ratio of irrigated area to the demand volume can be estimated, Table (6). WUE is evaluated depended on the ratio of irrigated area for each canal to the amount of total volume demand for this canal, the results of this evaluation show that the maximum value of the estimated WUEs was at Al-kamalea canal which is 7.9 km²/m³/sec. While the minimum value was at Al-ajmea canal which is 1.6 km²/m³/sec. The average WUE for the study area was 7.2 km²/m³/sec, which is equal to the WUE of Al-Huassainiyah canal.

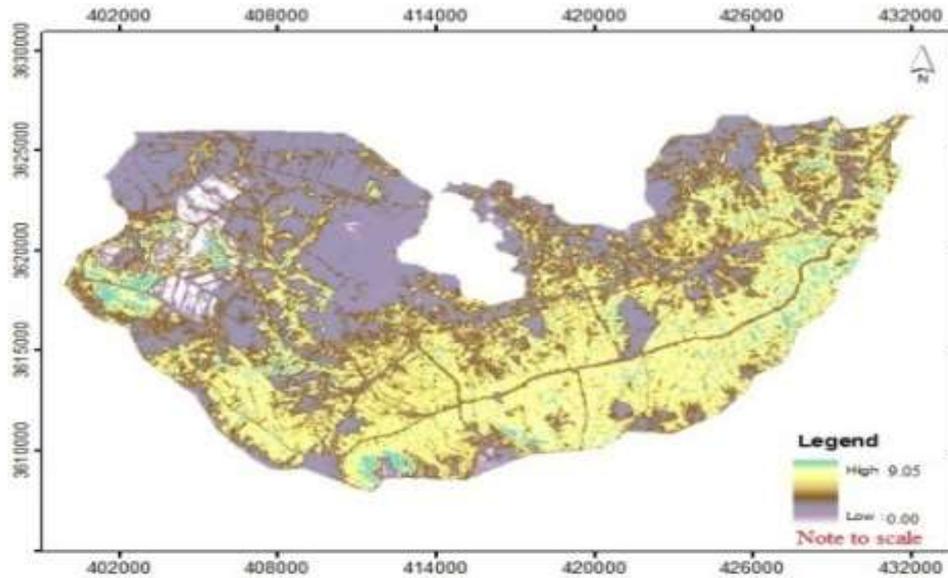


Figure (2): Estimated RVI.

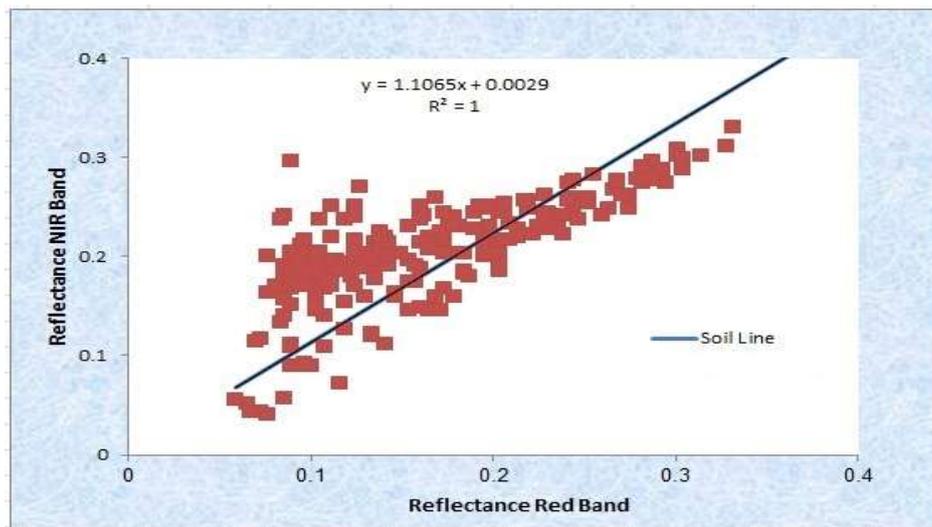


Figure (3): Soil line.

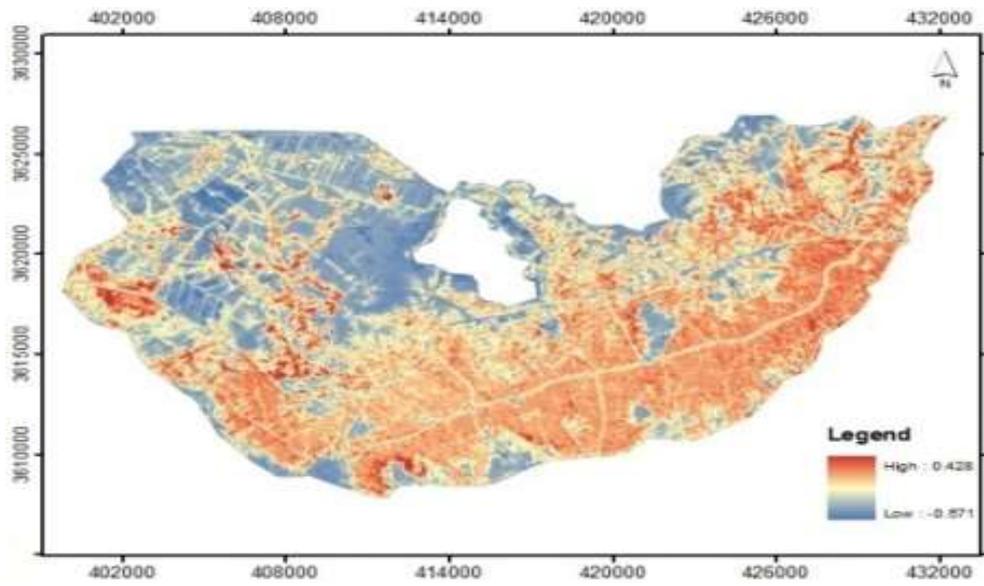


Figure (4): Estimated WDVI.

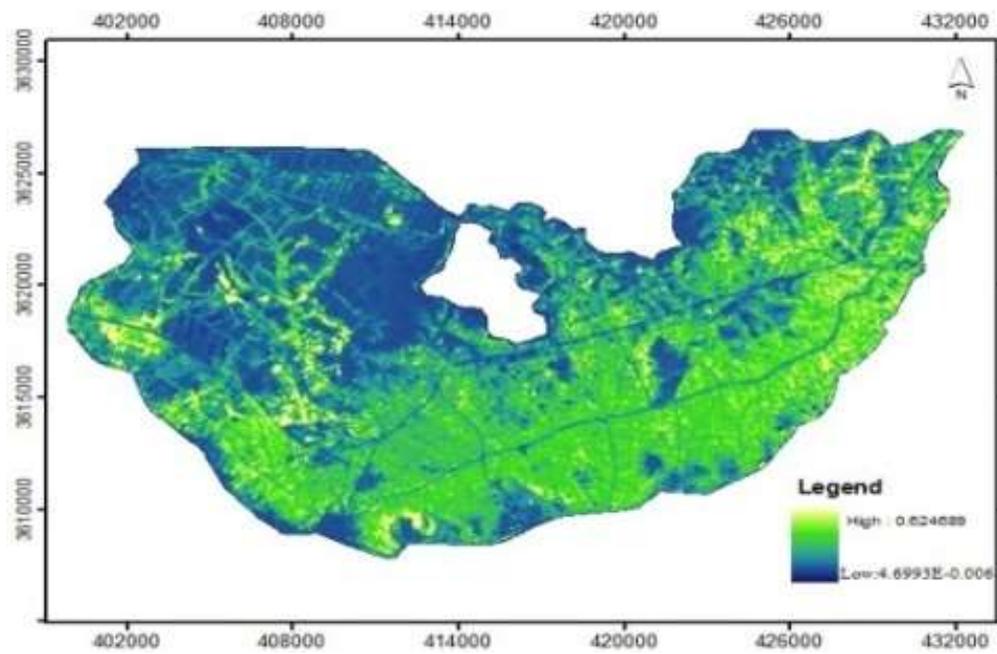


Figure (5): Estimated LAI.

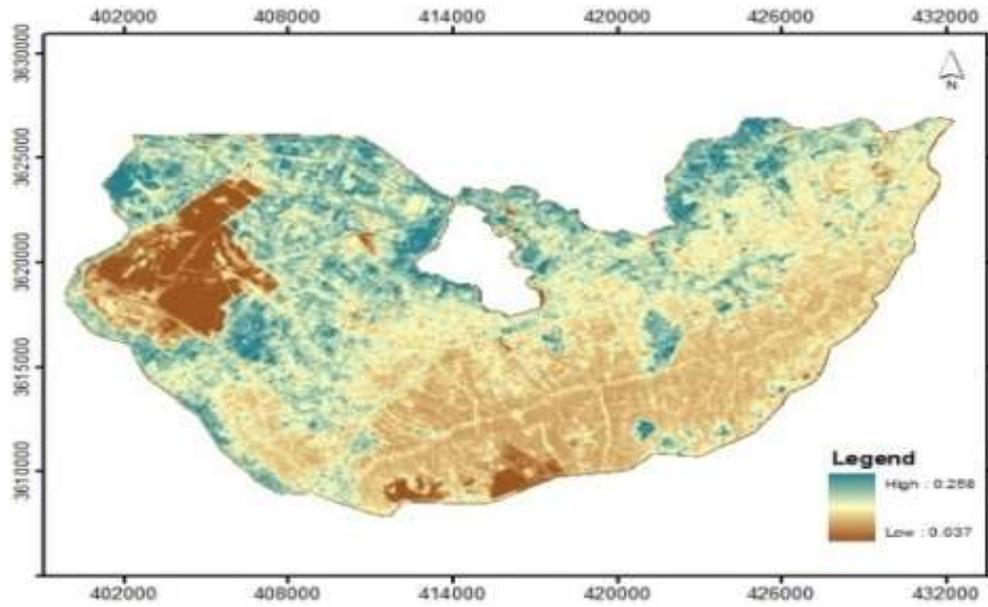


Figure (6): Estimated α .

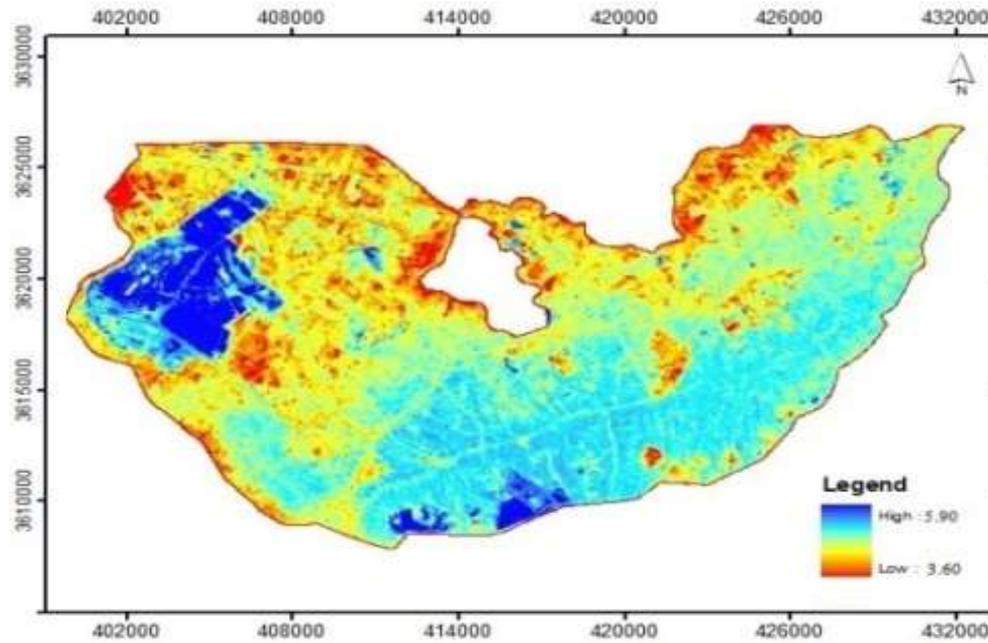


Figure (7): Estimated ET_c of the day Sept. 3, 2007.

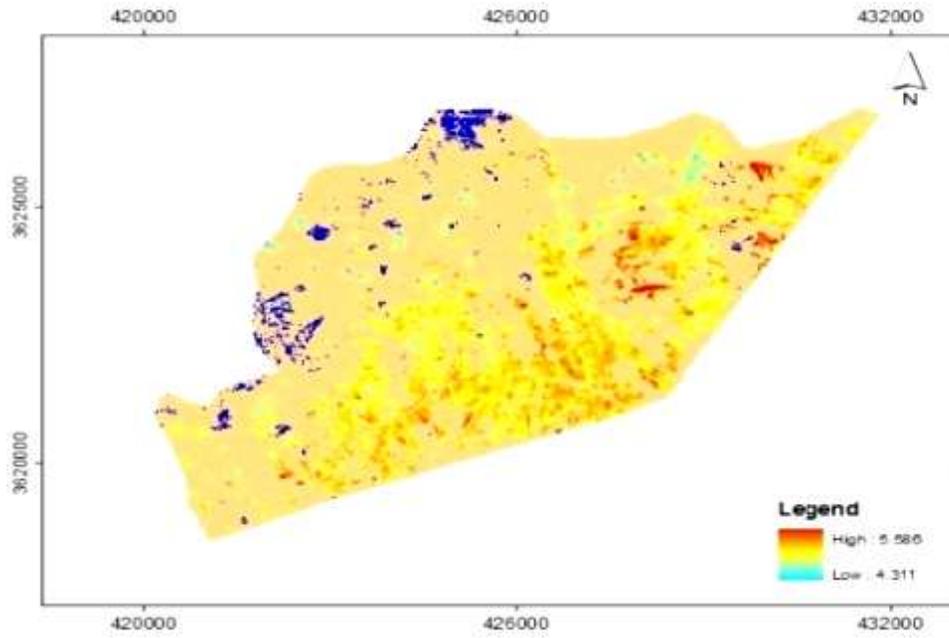


Figure (8): Estimated ET_C within Al-wand Canal sector.

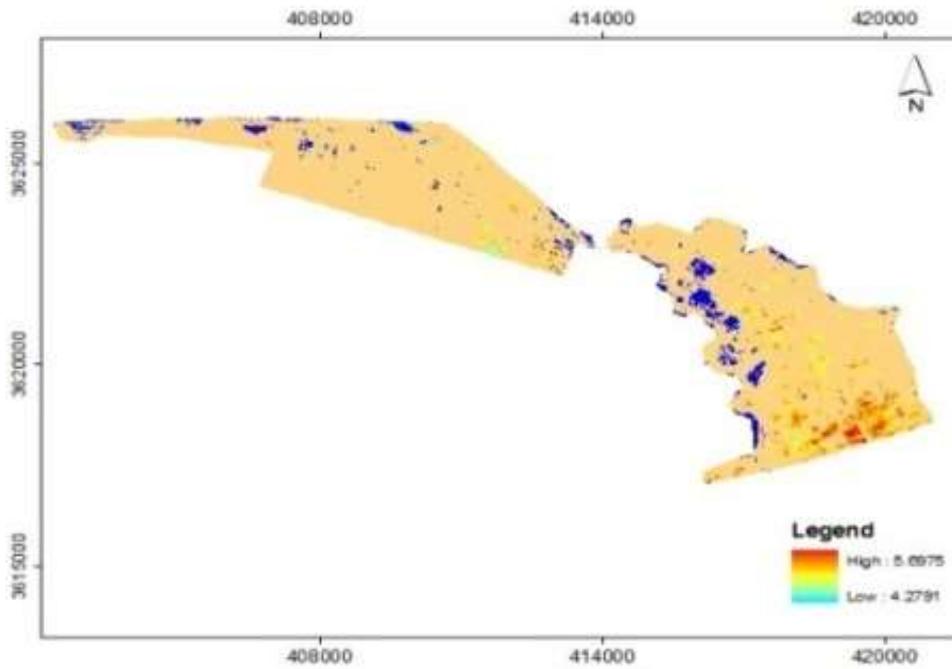


Figure (9): Estimated ET_C within Al-kamalea Canal sector.

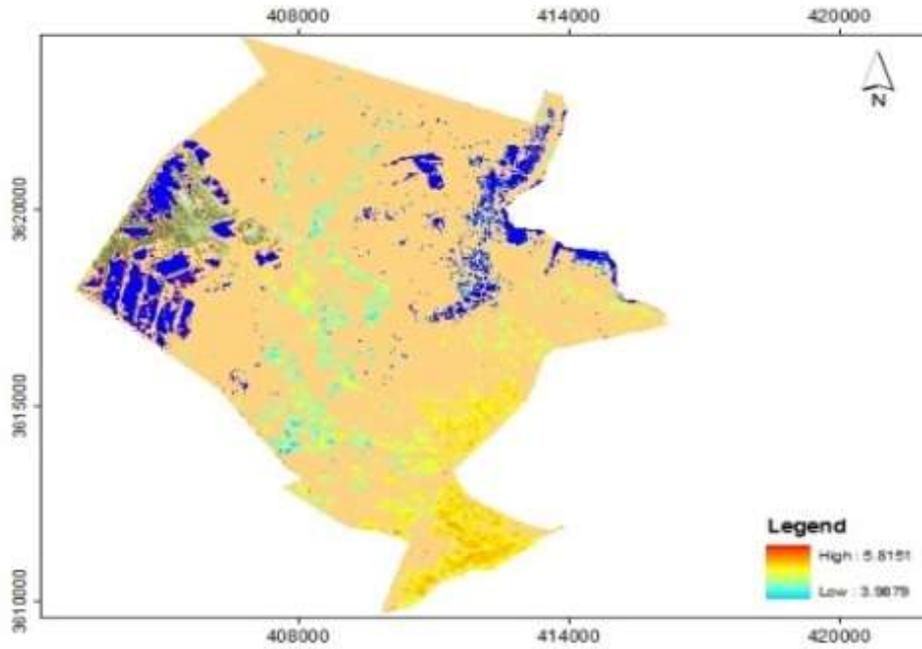


Figure (10): Estimated ET_c within Abu-zaraa Canal sector.

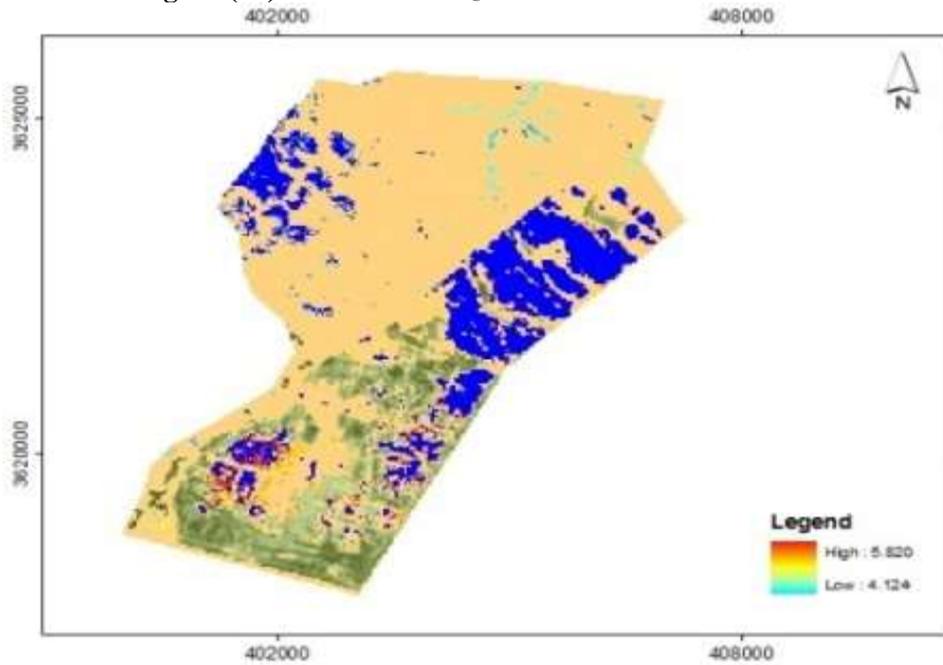


Figure (11): Estimated ET_c within Al-ajmea Canal sector.

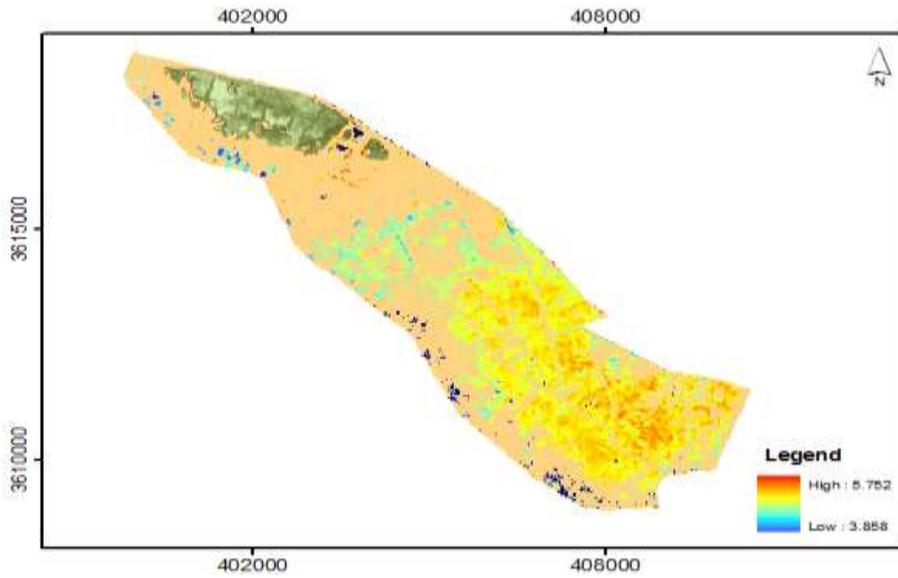


Figure (12): Estimated ET_C within Al-rashdaya Canal sector.

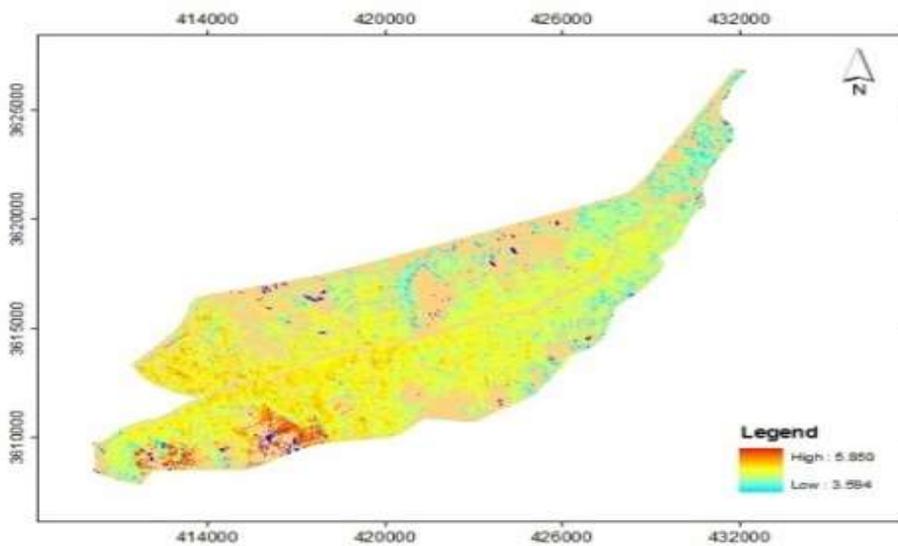


Figure (13): Estimated ET_C within Al-Hussainiyah Canal sector.

Table (5): Estimated ET_C for the six sectors

No.	Sector Name	ET_C (mm/day)
1	Al-wand Canal	5.05
2	Al-kamalea Canal	5.00
3	Abu-zaraa Canal	5.06
4	Al-ajmea Canal	5.29
5	Al-rashdyah Canal	5.13
6	Al-Hussainiyah Canal	5.22

Table (6): Water Use Efficiency (WUE).

No.	Sector Name	Vegetation Area (km ²)	Demand (m ³ /sec)	Water use efficiency (km ² / m ³ /sec)
1	Al-wand Canal	13.45	1.82	7.4
2	Al-kamalea Canal	2.93	0.37	7.9
3	Abu-zaraa Canal	12.67	1.71	7.4
4	Al-ajmea Canal	0.39	0.25	1.6
5	Al-rashdyah Canal	12.20	1.55	7.8
6	Al-Hussainiyah Canal	89.82	12.45	7.2
Total		131.46	18.17	7.2

CONCLUSIONS

The use of satellite data gives an integrated assessment of WUE in Al-Huassainiyah irrigation project through producing spatial representation to the values of water consumptions and WUE. The results of this study show that the WUE in Al-Huassainiyah irrigation project ranged between low and medium values. The maximum value of the estimated WUE was at Al-kamalea canal 7.9 km²/m³/sec. While the minimum value was at Al-Huassainiyah canal 7.2 km²/m³/sec, which is equal to the overall WUE of the study area. The WUE of Al-Ajmea canal is 1.6 km²/m³/sec because most of the area of this sector is swamp.

Most of the high values of the WUE extended along the main channels of the project because most of the cultivated area for the project distributed along these canals while most of the irrigation network operated under half of their design discharge and there are large areas not develop yet because of inefficient use of the irrigation network and lack of the enough water. This indicates that the weakness in monitoring, management and control of this project, causing a waste of large amounts of water and reduce the water use efficiency.

It has been proven that the Landsat 5 TM image can be effectively used in monitoring irrigation network, especially when looking at large area. It can be used for estimating and evaluating the water consumption and the water use efficiency of the irrigation projects in Iraq.

REFERENCES

- [1]. Akkartal, A., Türüdü, O. and Erbek, F. S. (2004). Analysis of changes in vegetation biomass using multitemporal and multi-sensor satellite data. XXth ISPRS Congress, July 2004, Istanbul, Turkey
- [2]. Allen, R.G., Pereira, Raes D., and Smith, M., 1998. "Crop Evapotranspiration, Guide lines for Computing Crop Water Requirements", Irrigation and Drainage Paper No. 56, Food and Agriculture Organization of the United Nations.
- [3]. Chander G., Markham Brian L., Helder Dennis L., 2009, "Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors". International Journal of Remote Sensing of Environment 113 893–903.
- [4]. Chander Joshi Prem, 2011, "Performance Evaluation of Vegetation Indices Using Remotely Sensed Data". International Journal of Geomatics and Geosciences. Volume 2, No. 1.
- [5]. Clevers, J. G. P. W., 1988: "The derivation of a simplified reflectance model for the estimation of leaf area index", RSE, 25: 53-69.

- [6].D'Urso, G. 2001. "Simulation and Management of On-Demand Irrigation Systems: A Combined Agrohydrological and Remote Sensing Approach ". Doctoral Thesis Wageningen University – with ref.- summary in Dutch and in Italian. ISBN 90-5808-399-3.
- [7].D'Urso, G., Menenti, M., 1995. "Mapping Crop Coefficients in Irrigated Areas from Landsat TM images; Proceed". European symposium on satellite remote sensing II, Europto, Paris, sett.'95; SPIE. Intern. Soc. Optical Engineering, 2585. pp. 41-47.
- [8].ERDAS, Inc., 2008. ERDAS Field Guide, ERDAS Inc., Atlanta, GA.
- [9].Jennings, D., 2002. "A pilot Study: Using Knowledge-Based Classification to Identify Springs in a Portion of the Sewickley Creek Basin, Pennsylvania", M. Sc Thesis, Department of Geology and Geography, College of Art and Sciences, West Virginia University, Virginia, UAS, URL <http://www.geo.wvu.edu/~warner/students.php>.
- [10].Kadam S. A., Gorantiwar S. D., Das S. N., Joshi A. K., 2014. "Estimation of Actual Evapotranspiration by Remote Sensing". International Journal of Innovative Research in Science, Engineering and Technology. Volume3, Special Issue 4, April.
- [11].Landsat 7 Science Data Users Handbook , 1997. NASA.
- [12].Shunlin, 2000 "Narrowband to Broadband Conversion of Land Surface Albedo I Algorithms", Remote Sensing of Environment, 76, 213-238,.
- [13].Liang Shunlin, Shuey Chad j., Russ Andrew L., Fang Hongliang, Chen Mingzhen, Walthall Charles L., Daughtry Craig S. T., Jr. Raymond Hunt, 2002. "Narrowband to Broadband Conversion of Land Surface Albedo: II. Validation", Remote Sensing of Environment, 84, 25-41.
- [14].MoA (Ministry of Agriculture), Directorate of Agriculture in Karbala Province, Department of Statistics, and Agricultural Divisions, 2014. "Unpublished Data about the State of Agriculture during (2006-2013) in Karbala " Iraq, (in Arabic).
- [15].MoAI (Ministry of Agriculture and Irrigation), State Organization for Land Reclamation, and Engineering Consulting Bureau at University of Technology, 1990. "The Economic Feasibility Study of Al-Hussainiyah Irrigation Project in Karbala Province", Technical report, Baghdad, Iraq, (in Arabic).
- [16].MoI (Ministry of Irrigation), 1982. "General Scheme of Water Resources, and Land Development in Iraq", Volume III, Books 1 and 2.
- [17].MoT (Ministry of Transportation), Karbala Meteorological Station, 2014, "Unpublished Climatic Data", Karbala, Iraq.
- [18].MoWR (Ministry of Water Resources), 2014, "Unpublished Recorded Hydrological Data" National Center for Water Resources Management, Baghdad-Iraq.
- [19].Papadavid G.; Hadjimitsis D.; Toullos L., Michaelides L. (2011). Mapping Potatoes Crop Height and LAI through Vegetation Indices using Remote Sensing, in Cyprus Journal of Applied Remote Sensing 5, 053526 (2011), DOI:10.1117/1.3596388.
- [20].Richardson, A. J., and Wiegand C. L., 1977. "Distinguishing Vegetation From Soil Background Information", Photogrammetric Engineering and Remote Sensing, 43(12):1541-1552.
- [21].Rohitashw Kumar, Vijay Shankar, and Mahesh Kumar, 2011. "Modeling of Crop Reference Evapotranspiration". Universal Journal of Environmental Research and Technology. Eurasian Publishing Company, 3: 239-246.
- [22].Sellers, P. J., Mintz, Y., Sud, Y. C., and Dalcher, A. 1986. A simple biosphere model (SIB) for use within general circulation models, J. Atmos. Sci. 43:505-531.

- [23].Silleos, N.G., Alexandridis, T.K., Gitas, I.Z. & Perakis, K. 2006. Vegetation Indices: Advances made in Biomass Estimation and Vegetation Monitoring in the last 30 Years, *Geocarto International* 21 (4) 21–28.
- [24].Smith, R. B., 2010. "The Heat Budget of The Earth's Surface Deduced From Space", available http://www.yale.edu/ceo/Documentation/ceo_faq.html. (last date accessed: July 12, 2014).
- [25].Taweasuk Siripun, Thammapala Prasong, 2005. "Expert Classification Technique for Mapping Teak Plantation Areas in Thailand". *Global Priorities in Land Remote Sensing*. October 23 – 27, 2005. Sioux Falls, South Dakota.
- [26].Wallin Dived, 12, 13, 2006. "Spatial Analysis Lab (SAL)". Huxley Collage of Environment. URL:http://www.wvu.edu/huxley/spatial/tut/ERDAS_subset.htm (last date accessed: July 26, 2014).