Estimation of Land Surface Temperature for Different Regions in Iraq Using Remote Sensing Technique (ETM+)

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ABSTRACT

Temperatures are important factors that have an impact directly and indirectly on human, so the attention to this aspect certainly will be in the interest of human life.
In this research, the land surface temperature was estimated for different regions in Iraq, using the thermal Band of ETM+ sensor mounted in the Landsat 7 satellite. By using ERDAS 8.4 software, the thermal images are converted to thematic maps which represent land surface temperatures. The results showed that the estimated land surface temperatures are 29.7°C, 31.8°C, 17°C, 17.8°C, 17°C, 20.6°C and 30.2°C for Al-Mousl , Taleafer, Al-Ramadi, Heet, Kerbela, Al-Hai and Al-Basrah stations respectively. Also the results show that there is high correlation between the estimated and the observed data with a difference of 1-2°C.

Keywords: Landsat, Land surface temperature, Remote sensing. Iraq.

تخمين درجات الحرارة السطحية لمناطق مختلفة من العراق باستخدام تقنية الاستشعار عن بعد (ETM+)

الخلاصة

تعتبر درجة الحرارة من العوامل المهمة والتي لها تأثير مباشر وغير مباشر على الانسان, لذا فأن الاهتمام بهذا الجانب بالتأكيد سينصب في مصلحة الحياة البشرية . في هذا البحث تم تخمين درجات الحرارة السطحية لمناطق مختلفة من العراق باستخدام القناة الحرارية للمتحسس ETM+ المحمول على القمر الصناعي Landsat 7. باستخدام برنامج الايرداس 8.4 حيث تم تحويل الصور الحرارية الى خرائط غرضية توضح درجة حرارة السطح .أظهرت النتائج بان درجة الحرارة المخمنة لمحطات الموصل ,تلعفر, رمادي, هيت, كربلاء, الحي والبصرة هي 29.7°C, 31.8°C, 17.8°C,17°C , 20.6°C,17°C و 30.2°C على التوالي . كما اظهرت النتائج وجود علاقة ارتباط قوية بين البيانات المخمنة والبيانات المقاسة مع اختلاف من 1 الى 2 °C.

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INTRODUCTION

Satellite data are very useful in various applications like, astronomy, atmospheric studies, earth observation, communications, navigation, search and rescue. Land surface temperature is an important parameter in the field of atmospheric sciences as it combines the result of all surface-atmosphere interaction and energy fluxes between the ground and the atmosphere and is, therefore, a good indicator of the energy balance at the Earth's surface[1].

Land surface temperature can provide important information about the surface physical properties and climate which plays a role in many environmental processes [2]. Many studies have estimated the relative warmth of cities by measuring the air temperature, using land based observation stations. Some studies used measurements of temperature using temperature sensors mounted on car, along various routes [3].

A traditional way of estimating surface temperature is by using weather-station based meteorological observations. This method is not a feasible solution for all types of topographic conditions. But remote sensing technique is useful in any topographic and climatic condition of the region. Thermal infrared remote sensing provided an opportunity to estimate land surface temperature from thermal band images. Satellites are equipped with sensors which can detect a range of infrared heat. Estimation of surface temperature from satellite infrared radiometers has been proven useful. Most studies have focused on the use of polar orbiting satellite systems because of their high spatial resolution [4].

The Landsat-7 satellite with ETM+ sensor has been used in sensing spectral resolution range of 10.40 -12.5 (am) to capture the scene, the band 6 images is used in this study. Landsat-7 ETM+ has a high spatial resolution accuracy compared to other thermal sensors on other satellites, as well as the thermal imaging in this sensor is determined by two bands, one band is 6-1 where the acquisition the low gain, while the second band is 6-2, the acquisition will be high gain. In this paper, an attempt has been carried out to estimate surface temperatures for parts of the Iraq using Landsat (ETM+) imagery.

Thermal Infrared Remote Sensing

Thermal radiation results from random atomic and molecular motions and is emitted by all substances having a temperature above zero [5]. The thermal radiation was described by some scientists such as Plank, Stefan-Boltzmann, Wien, and Kirchhoff. Plank's radiation law related the spectral characteristics and magnitude of emission to the temperature of the emitting body; the expression for a perfect emitter or blackbody at any given wavelength [5].

$$E_\lambda = \frac{C_1}{\lambda^5\left(\exp\left(\frac{C_2}{\lambda T}\right)-1\right)} \quad \text{...} \quad (1)$$

Where, E_λ is the spectral emission (spectral radiant) in W/(m.µm), C_1 is the first rotation constant equal 3.7418×10^{-16} W.m^2, C_2 is the second radiation constant equal 1.44×10^{-2} m.^{o}K, T is the absolute temperature (^{o}K).

Equation (1) indicates that at any given wavelength, the total energy of the emitted blackbody radiation increases as temperature increase. It is also indicates that the intensity distribution of the radiation various with wavelength at a given temperature. So the values for E_λ are commonly used to construct energy distribution curves for objects at various temperature.

The magnitude of radiation emitted from blackbody over entire spectrum is explained by the Stefan-Boltzmann law [5].

$$E_b = \sigma T^4 \qquad \text{... (2)}$$

Where:

E_b is the radiant emittance from a blackbody in W/m^2, σ is Stefan-Boltzmann constant equal 5.67×10^{-8} W/(m^2.^{o}K^4), T is the absolute temperature (^{o}K).
Equation (2) shows that the total energy emitted from overall blackbody wavelength, is directly proportional to the fourth power of its absolute temperature. For example if the temperature of blackbody is raised from 300 ^{o}K to 600 ^{o}K, its temperature is doubled; but the radiant emittance increases 16 times.
Wien's displacement identifies the wavelength at which the maximum amount of energy is radiated (λ_{max}) from blackbody [5].

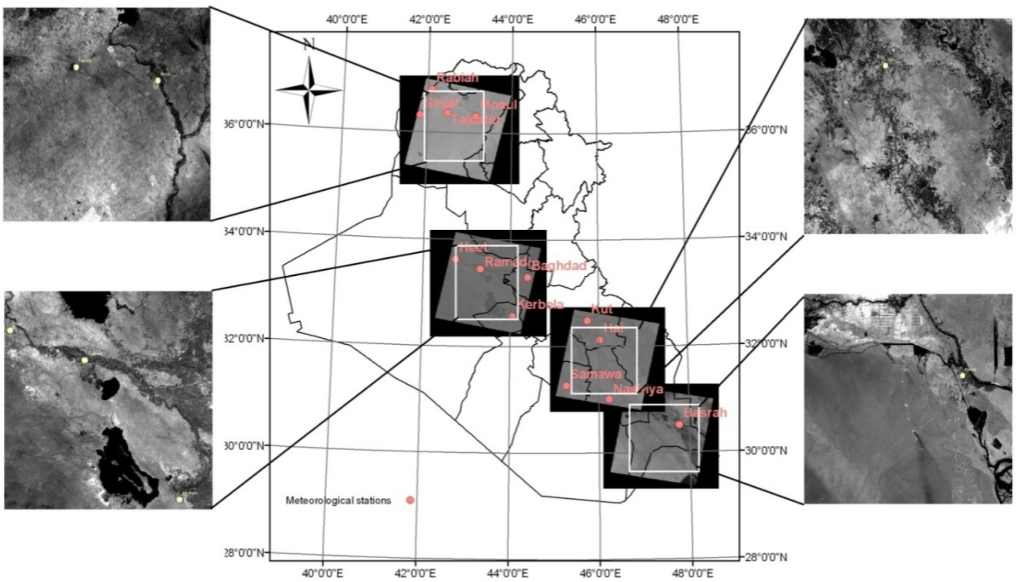
$$\lambda_{max} = \frac{W}{T} \qquad \text{... (3)}$$

W is Wien's displacement constant equal 2897.8 µm °K. Wien's displacement law shows that the wavelength of maximum energy emission is inversely proportional to the absolute temperature of the blackbody.

Studying Area and Data Acquisition

Studying Area

Iraq is located in the South-West of Asia, to the north-east of the Arab homeland, bounded on the North by Turkey, on the East by Iran, on the West by Syria, Jordan and Saudi Arabia and on the South by Arab Gulf Kuwait and Saudi Arabia. Iraq lies between latitudes 29˚ 5´ and 37˚ 22´ north and between longitudes 38˚ 45´ and 48˚ 45´ east. The whole investigation areas cover 12 meteorological stations in Iraq are Al-Mousl , Taleafer, Al-Ramadi, Heet, Kerbela, Al-Hai and Al-Basrah, as shown in Figure 1.



Figure(1): Map of Iraq and study area

The climate of Iraq is mainly of the continental, subtropical semi-arid type, with the north and north-eastern mountainous regions having a Mediterranean climate. The average annual rainfall is estimated at 216 mm, but ranges from 1200 mm in the northeast to less than 100 mm over 60 percent of the country in the south. Winters are cool to cold, with a day temperature of about 16 °C dropping at night to 2 °C with a possibility of frost. Summer seasons are dry and hot to extremely hot, with a shade temperature of over 43 °C during July and August, yet dropping at night to 26 °C [6].

Data Acquisition

The data has been acquired mainly from two sources; firstly Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and secondly daily temperature data acquired from the Iraqi Meteorological Organization and Seismology (IMOS).
Landsat satellites have been collecting images of the earth's surface for more than forty years. NASA (National Aeronautics and Space Administration) launched the first Landsat satellite in 1972, and the most recent one, Landsat 7, in 1999. Currently, only the Landsat 5 and 7 are still operating normally. Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+). The landsat Thematic Mapper (TM) and Enhanced landsat Thematic Mapper Plus (ETM+) sensors acquire temperature data and store this information as a digital number with range between 0 and 255.
Four scenes of satellite image had been used in a different place and time, as shown in Figure 2, These images are freely available from the Landsat archive in the United States Geological Survey (USGS) website (http://glovis.usgs.gov). Table 1 shows the details of satellite images of the study area.

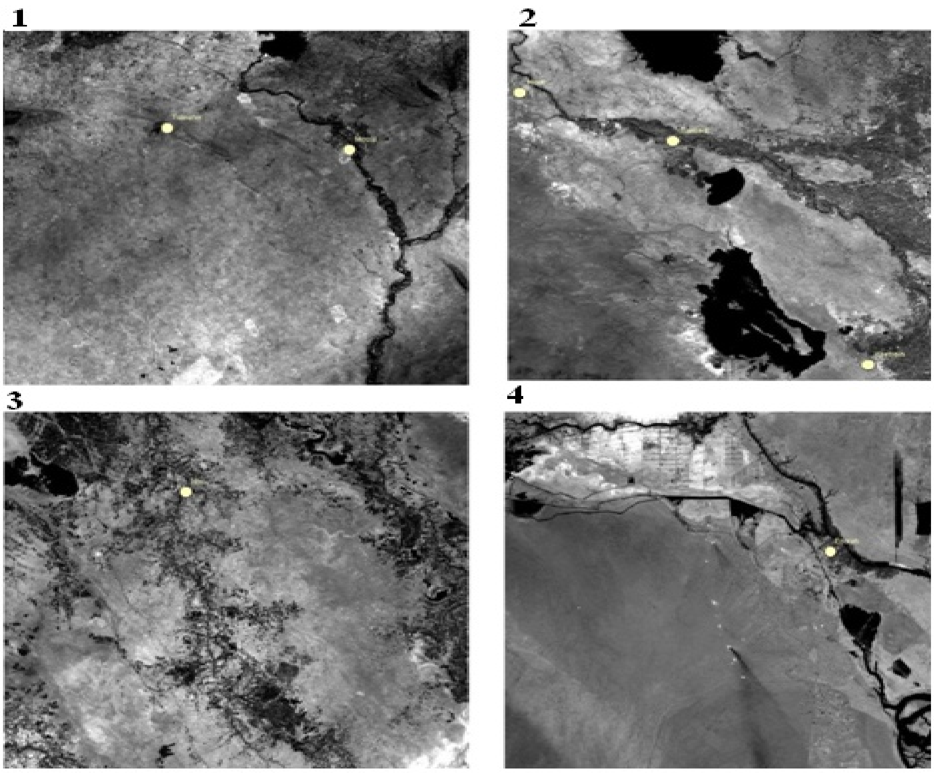


Figure (2): Representation study area clipping from original satellite images

Table (1): information of Landsat image used in the study

Landsat image	Acquisition Data	Projection	Datum	Sun Elevation	Sun Azimuth
1	13-June-2001	UTM Zone 38 North	WGS 84	65.92	115.67
2	18-March-2001	UTM Zone 38 North	WGS 84	48.04	138.997
3	20-March-2001	UTM Zone 38 North	WGS 84	49.674	137.037
4	24-September-2002	UTM Zone 38 North	WGS 84	52.264	139.847

Methodology

The strong absorption in the infrared region allows the calculation of the surface temperature from satellite thermal channels. The infrared radiance measured from a satellite can be converted to surface radiance by applying the Emissivity Normalization method. The surface radiance is then converted to surface temperature. The methodology followed is schematically shown in Figure 3.

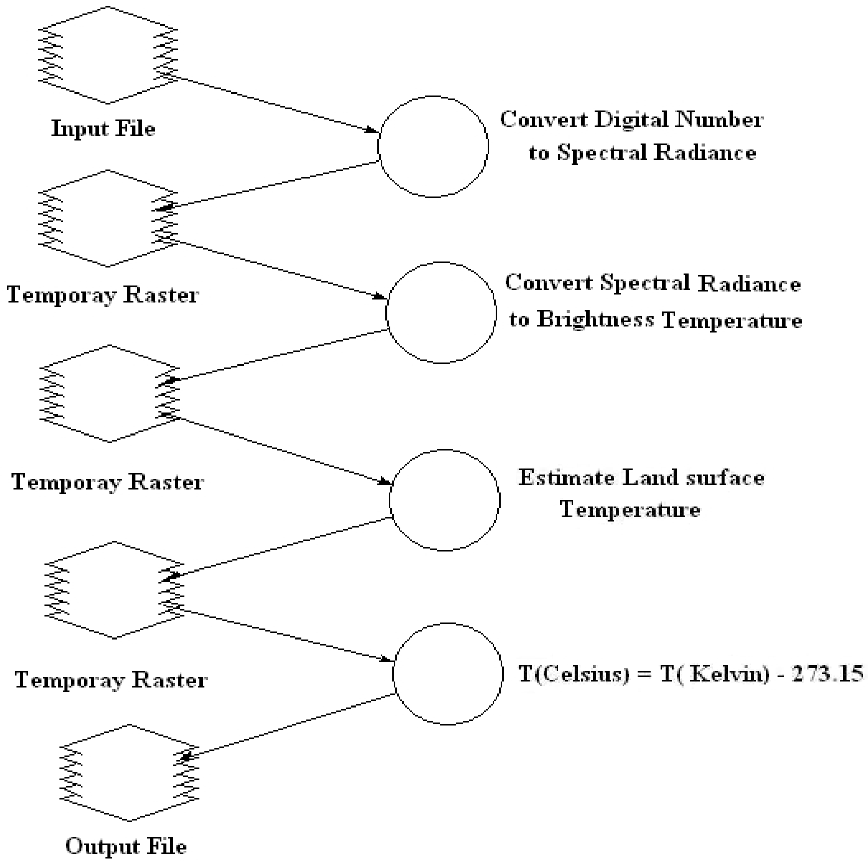


Figure (3): Flow chart showing work steps in this study

Work steps

Step 1

The Digital Number (DN) of thermal infrared band is Converted to Spectral Radiance (L_λ) using the equation supplied by Landsat user's hand book [7].

$$L_\lambda = L_{MIN} + \frac{(L_{Max} - L_{MIN}) \times DN}{MaxGray} \quad \ldots \quad (4)$$

Where: L_λ is the Spectral Radiance at the sensor's aperture in $Wm^{-2}sr^{-1}\mu m^{-1}$, L_{Max} and L_{MIN} are the Maximum and minimum radiance values for a given band, $MaxGray$ is the Maximum number of gray value and DN is the digital number for a given band.

L_{Max} and L_{MIN} are obtained from Meta data file available with the image and are given in Table 2 below.

Table(2): L_{Max} and L_{MIN} values of Landsat data.

Band No.	Satellite/ Sensor	L_{Max}	L_{MIN}
6.1	Landsat/ ETM+ High gain	12.62	3.2
6.2	Landsat/ ETM+ Low gain	17.04	0.0

Step 2

The effective at sensor brightness temperature (T_B in Kelvin) also known as black temperature is obtained from the spectral radiance using approximation formula [7].

$$T_B = \frac{K_2}{\ln(1 + \frac{K_1}{L_\lambda})} \quad \ldots \quad (5)$$

The calibration constants K_1 and K_2 obtained from Landsat user's manual are given in the Table 3 below.

Table (3): calibration constants for thermal band

Sensor	K_1	K_2
Landsat/ ETM+	666.09	1282.71

Step 3

The final Land Surface Temperature (LST) is estimated by following equation [7].

$$LST = \frac{T_B}{1+\left(\lambda+\frac{T_B}{\rho}\right).\ln\varepsilon} \quad \ldots \quad (6)$$

where, λ is the wavelength of the emitted radiance which is equal to 11.5µm. ρ= h.c/σ, σ is Stefan Boltzmann's constant which is equal to 5.67 x 10^{-8} $Wm^{-2o}K^{-4}$, h is Plank's constant(6.626 x 10^{-34}J sec), c is velocity of light (3 ×10^8 m/sec) and ε is the spectral emissivity. In this study spectral emissivity coefficient is taken for black body.

The temperatures are estimated in degrees Kelvin, and are then converted to degree Celsius by T (Kelvin) – 273.15.

All these steps were developed using Spatial Modeler of ERDAS Imagine 9.4.

Results and Discussion

Figures 4(A), (B), (C) and (D) show the spatial distribution of the land surface temperature in Iraq, derived from Landsat (ETM+) data obtained on 13 June 20013, 18 March 2001, 20 March 2001 and 24 September 2002 respectively. A comparison with ground based measurements was used to validate the estimated surface temperature values. The observation was carried out 13 June 20013, 18 March 2001, 20 March 2001 and 24 September 2002 at the same local standard time (10:00).

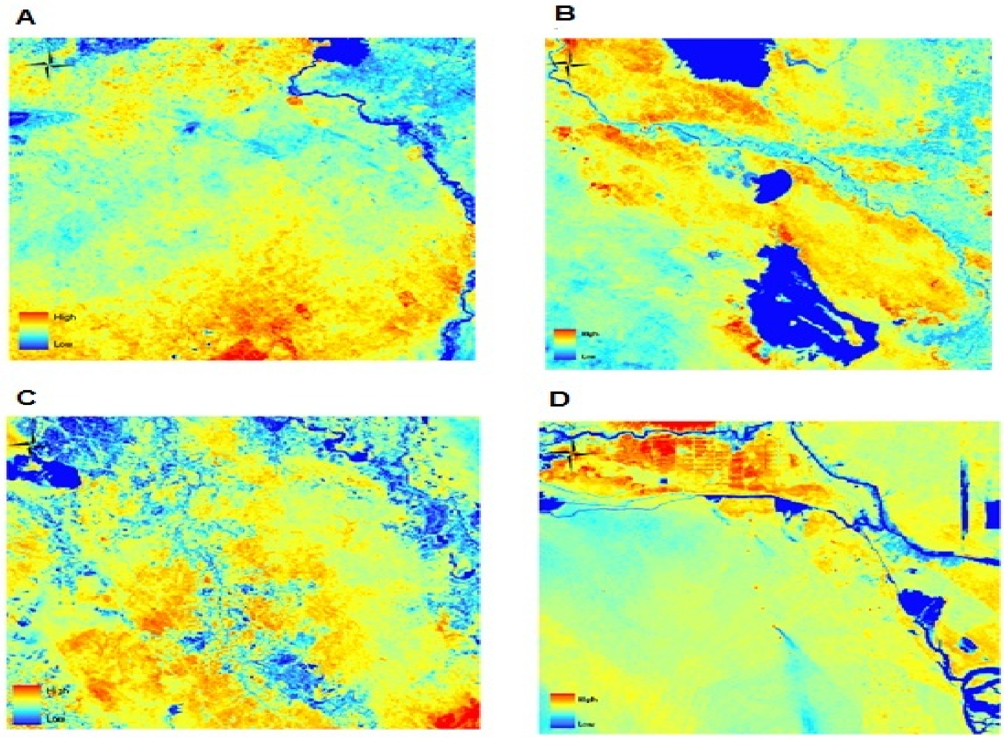


Figure (4): The land surface temperature pattern distribution map

Table 4, is the comparison of air temperature(Observed) and land surface temperature (Estimated) in seven meteorological stations (Al-Mosul, Taleafer,Al-Ramadi, Heet, Kerbela, Al-Hai and Al-Basrah).

Table (4): A Comparison between the observed and the retrieved surface temperature data for selected meteorological stations.

Date	Station	Observed Temperature (°C)	Estimated Temperature (°C)
13-June-2001	Al-Mosul	28	29.7
13-June-2001	Taleafer	30.5	31.8
18-March-2001	Al- Ramadi	15.6	17
18-March-2001	Heet	16.6	17.8
18-March-2001	Kerbela	15.2	17
20-March-2001	Al-Hai	18.8	20.6
24-September-2002	Al-Basrah	28.7	30.2

The results are then compared with the observed data from the Iraqi Meteorological Organization and Seismology (IMOS) yielding a high correlation (0.98), with differences of 1- 2^{o}C.

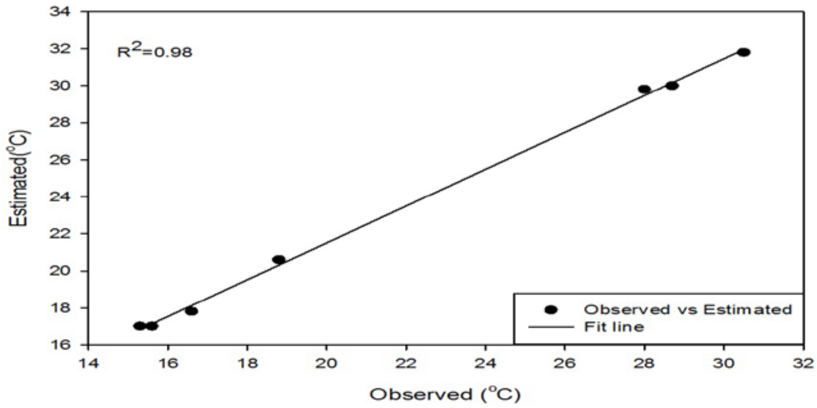


Figure. 5: The relationship between the observed data and the estimated data for selected meteorological stations

Conclusion

In this study, the application of Landsat (ETM+) imagery for estimating land surface temperature and air temperature for different regions in Iraq, using the observed relationship between land surface temperature and air temperature, was investigated. The results showed a strong correlation between land surface temperature and air temperature measurements in both years indicating that the Landsat surface temperature value provides a reliable representation of the actual LST. The range of determination coefficient (R^2) between air temperature and land surface temperature was 0.98 with differences of 1- 2 ^{o}C. Therefore, land surface temperature can be used as an indicator of air temperature.

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