Preparing a Map for the Surface Temperature Distribution of Baghdad and the Marsh Area Using Remote Sensing Technique

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Abstract

Temperatures are important factors that have an impact directly and indirectly on the human, so the attention to this aspect certainly will be in the interest of human life. It is no secret to anyone increased warming and cause concern in the scientific authorities. On this basis, interested search to produce digital map and classified chromatically for the temperature distribution and by taking advantage of the band 6 of the satellite Landsat ETM+ and TM, also introduced in the calculations standards sensor satellite mentioned within emissions equations for the purpose of extracting this map.

Namely, that it is possible to know the temperature of any point in the study site through color classification of this map and easily find out the temperature of that site by color groups belonging to that class. As used thermal images belonging to the study area for consecutive periods of time for the purpose of knowledge over the difference in temperatures for that area during a certain period of time, Where the research show that the study area (Baghdad in the middle of Iraq and marshes in southern Iraq) suffering from a rapid increase in temperature, which reflected negatively on the ecology of the area specially in marshes. The method used in research can be applied using ENVI software to any part of the areas of Iraq as soon as you get the thermal band of Landsat ETM+ and TM, this method may lead to detect heat sources unknown and unexpected areas of difficult access and measure the temperature.

Keywords: Thermal remote sensing; Digital surface temperature; Thermal radiation to surface temperature; Convert digital to radiance; Surface temperature.

اعداد خارطة لتوزيع درجات الحرارة السطحية لمحافظة بغداد ومنطقة الاهوار باستخدام تقنية الاستشعار عن بعد

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الخلاصة

تعتبر درجات الحرارة من العوامل المهمة والتي لها تأثير مباشر و غير مباشر على الإنسان، لهذا فأن الاهتمام بهذا الجانب بالتأكيد سينصب في مصلحة الحياة البشرية. ولا يخفى على احد زيادة درجات حرارة الأرض وبشكل يبعث القلق في الجهات العلمية المختصة. وعلى هذا الأساس اهتم البحث على إنتاج خارطة مصنفة لونيا لتوزيع درجات الحرارة وذلك بالاستفادة من الحزمة السادسة للساتل Landsat ولكل من المتحسسات TM و +ETM, مع الاخذ بنظر الاعتبار معايير المتحسسات المذكورة ضمن معادلات الانبعاث الحراري لغرض استخلاص الخارطة الحرارية. أي انه من الممكن معرفة درجة الحرارة لأي نقطة في موقع

الدراسة وبسهولة من خلال التصنيف اللوني لها, وذلك بالرجوع إلى تصنيف الفئة اللونية وما يقابلها من درجة حرارة على سطح الأرض. ولغرض معرفة مدى الاختلاف الحاصل في درجات الحرارة لتلك المنطقة خلال فترة زمنية معينة استخدمت صور حرارية تخص منطقة الدراسة ولفترات زمنية متتابعة, حيث بين البحث إن مناطق الدراسة (بغداد في وسط العراق ومنطقة الاهوار الواقعة في جنوب العراق) تعاني من زيادة متسارعة في درجات الحرارة والتي انعكست بشكل سلبي على البيئة الاحيائية لتلك المنطقة وخصوصا في منطقة الاهوار. أما الطريقة المستخدمة في البحث فيمكن تطبيقها على اي جزء من مناطق العراق بمجرد الحصول على الحزمة الحرارية السادسة للساتل Landsat TM و Landsat ETM+ وقد تؤدي هذه الطريقة إلى الكشف عن مصادر حرارية مجهولة وغير متوقعة وفي مناطق من الصعب الوصول إليها وقياس درجة حرارتها.

1- Introduction

Pixel values in commercially available satellite imagery represent the radiance of the surface in the form of Digital Numbers (DN) which are calibrated to fit a certain range of values. Sometimes the DN are referred to as the brightness values. Conversion of DN to absolute radiance values is a necessary procedure for comparative analysis of several images taken by different sensors (for example, Landsat-2 versus Landsat-5). Since each sensor has its own calibration parameters used in recording the DN values, the same DN values in two images taken by two different sensors may represent two different radiance values.

Usually, detectors are calibrated so that there is a linear relationship between DN and spectral radiance. This linear function is described by three parameters: the range of DN values in the image, and the lowest (Lmin) and highest (Lmax) radiances measured by a detector over the spectral bandwidth of the channel. Most commonly, the data are distributed in 8-bit format corresponding to 256 DN levels.

LANDSAT Thematic Mapper (TM) 4-5: was launched in 1981-1984 .The TM acquires the image data in visible (band 1: 0.45-0.52, band 2: 0.53-0.61, and band 3: 0.63-0.69µm), near infrared (band 4: 0.78-0.90µm), short-wave infrared (band 5: 1.55-1.75 and band 7: 2.09-2.35µm), thermal infrared (band 6: 10.4-12.5µm). The spatial resolution is 30m in the visible, near infrared, and short-wave infrared bands, and 120m in the thermal infrared band. [1]

LANDSAT Enhanced Thematic Mapper (ETM+) 7: was launched on April 15th, 1999 and images large areas of the sunlight Earth daily by revisiting the same areas every 16 days. It has ETM+ sensor with the same bands in (TM) sensor, plus pan band (0.5-0.9µm), which has spatial resolution 15m. Spatial resolution of ETM+ in thermal band differ from spatial resolution in TM in the thermal band, so that ETM+ has spatial resolution in thermal band is 60m. and each scene represents the earth in 183 by 170 kilometers. [1]

The verification study on the surface temperature derived from the thermal infrared bands by image data of the TM and ETM+. TM thermal infrared data were used to derive surface temperature in Baghdad capital at 1990 and 1998 dates. While the ETM+ data used to verify the surface temperature to study the thermal condition in Al_Hammar marsh at 2000 and 2003 dates. We interested in processing the TM and ETM+ data because it is available to test the adopted procedure, also the new version of Landsat images could be applied to get the same results.

2- Marshes

In general, marsh is small lakes and ponds full , yellow iris, and many other types of plant life [2]. Marshes are frequently or continually flooded wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions, changing water flows and mineral soils [3]. Marsh is one type of wetlands is not "useless swamps" as they have often been perceived, but are among the most productive ecosystems in the world. Wetlands do much more than provide a home for wildlife. Wetlands are also natural sponges. When flood waters over flow the banks of streams and rivers the porous soils and plants of wetland soak-up tremendous amount of the excess water. Water then seeps slowly back into the stream to prevent downstream flooding. In times of drought,

wetlands are fed by ground water which is released into streams to keep them flowing year round [4].

1- Area and Location

Baghdad is the capital of the Republic of Iraq. The population of Baghdad as of 2011 is approximately 7,216,040, making it the largest city in Iraq, the second largest city in the Arab World (after Cairo, Egypt), and the second largest city in Western Asia (after Tehran, Iran).

The city is located on a vast plain bisected by the River Tigris. The Tigris splits Baghdad in half, with the eastern half and the Western half. Baghdad has a subtropical arid climate and is, in terms of maximum temperatures, one of the hottest cities in the world. Temperatures exceeding 50 °C (122 °F) in the shade, even at night temperatures in summer are seldom below 24 °C (75 °F). Winters boast mild days and variable nights. From December to February, Baghdad has maximum temperatures averaging 15.5 to 18.5 °C (60 to 65 °F).

In other hand, Iraqi marshes lies in the southern part of Iraq, the Iraqi marshes cut across three of Iraq's eighteen provinces: Misan (originally Al-Amarah), Dhi-Qar (originally Al-Nasiriyah), and Al-Basrah. The heartland of the marshes comprised three principal areas [5]:

1. The Al-Hammar marshes are located south of the Euphrates, extending from near Al-Nasiriyah in the west to the outskirts of Al-Basrah on the Shatt al-Arab, as in fig, 1.[6]
2. The Central marshes located immediately above the confluence of the two Mesopotamian rivers, bounded by Tigris river to the east and the Euphrates river in the south, the area is roughly delimited by a triangle between Al-Nasiriyah, Qalat Saleh and Al-Qurnah[6]
3. The Al-Hawaizah marsh, located east of the Tigris river and extending into Iran (where they are known as the Al-Azim marshes).[6]

During the hot, dry summers, daily marshes temperature ranged 68ºF (20ºC) at night to 104ºF (40ºC) during the day with maximum high of 122ºF (50ºC). In cold, wet winters, daily temperatures average from 41ºF(5ºC) to 59ºF (15ºC) with a low of 12ºF(-11ºC). Fig, 2 shows temperature distribution in Iraq.

Figure(1) show the location of study area used in this work. Baghdad location along the Tigris River and has geographical coordinates (44.1º - 45.5º) longitude and (32.2º –33.5 º) latitude. Marshes locally it extends between (46.4º-47.4º) longitude and (30.3º- 31.4º) latitude.

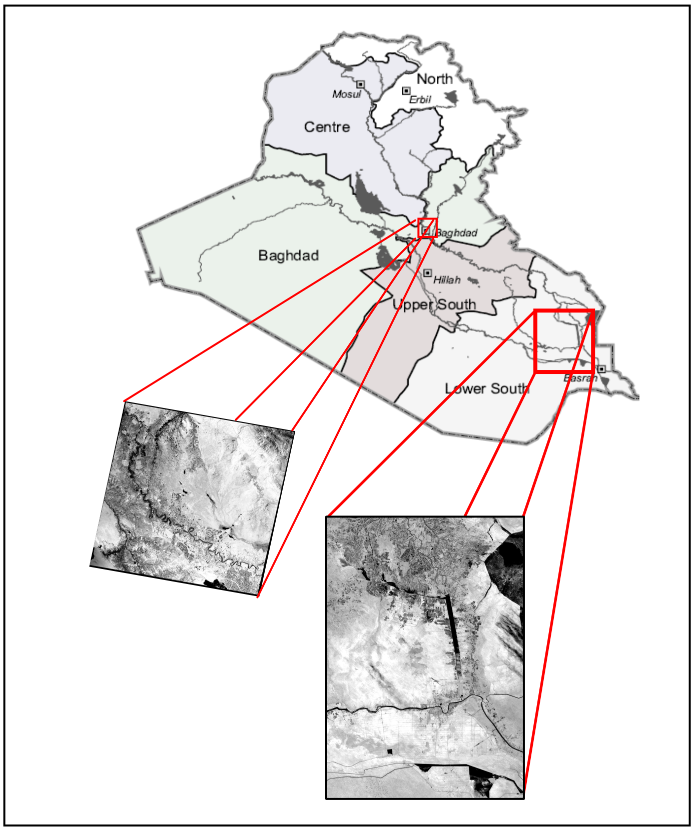


Figure 1- The Area Of Study. Baghdad To The Left, Al-Hammer Marsh To The Right.

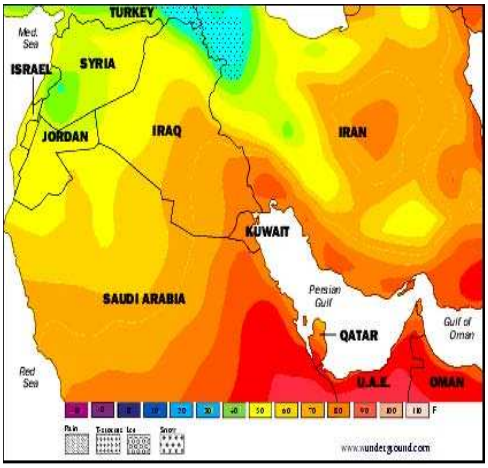


Figure 2- Temperature Distribution In

4- Thermal Infrared Remote Sensing

Thermal radiation results from random atomic and molecular motions and is emitted by all substances having a temperature above zero (0 k, -273.16ºC). [9] This thermal radiation was described by some scientists such as Plank, Stefan-Boltzmann, Wien, Kirchhoff. Plank's radiation law related the spectral characteristics and magnitude of the emission to the temperature of the emitting body; the expression for a perfect emitter or blackbody at any given wavelength. [5]

$$E_\lambda = C1 /\{ \lambda^5 \times [\exp (C2/ \lambda T) -1]\} \quad \text{………(1)}$$

Where

E_λ = spectral emission (spectral radiant) in $w/(m^2.\mu m)$.

C1 = first radiation constant = $2\pi hC^2$ $=3.7418\times10^{-16}$ $w.m^2$ (h=Plank's constant 6.6×10^{-34} J.Sec).

C2 = second radiation constant $=1.44\times10^{-2}$ m.K= (h.c/ k) (k is the Boltzmann's constant $=1.38\times10^{-23}$ $J.K^{-1}$).

T = absolute temperature (K).

Eq (1) indicates that at any given wavelength, the total energy of the emitted blackbody radiation increases as temperature increase. It also indicates that the intensity distribution of the radiation various with wavelength at a given temperature. So that values for E_λ are commonly used to construct energy distribution curves for objects at various temperatures, fig, 3.

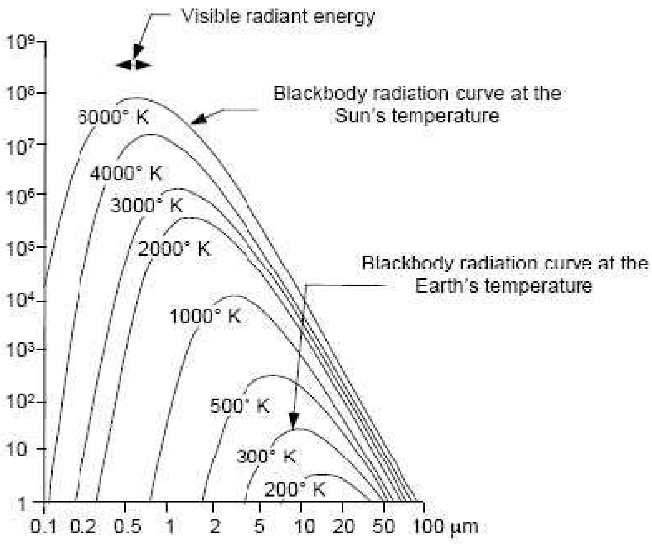


Figure 3- Blackbody Radiation Spectral Curves At Various Temperatures [5].

The magnitude of radiation emitted from a blackbody over entire spectrum (area under the curve in figure (3) is explained by the Stefan-Boltzmann law [9] :

$$E_{bb} = \sigma T^4 \quad \text{……..…. (2)}$$

E_{bb} = radiant emittance from a blackbody in w/m^2

$\sigma = 5.67\times10^{-8}$ $w/ (m^2.K^4)$ (Stefan-Boltzmann constant)

T = absolute temperature (K)

Eq (2) shows that the total energy emitted from overall blackbody wavelengths, is directly proportional to the fourth power of its absolute temperature. For example if the temperature of blackbody is raised from 300K to 600K, 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 a blackbody. [9]

$$\lambda_{max} = W/T \quad \ldots\ldots\ldots.(3)$$

T= Absolute temperature (K).

Wien's displacement law shows that wavelength of maximum energy emission is inversely proportional to the absolute temperature of the blackbody. Thus, as temperature increase, λmax shifts to progressively shorter wavelengths. Also Wien's displacement identifies the atmospheric windows to use for remote sensing thermal IR emission. For example, the radiant power peak for very hot targets such as sun is within or close to the 3to-5µm window (fig (3)). The 8-to-14µm window contains the radiant power peaks for most of the earth's passive features. Since their temperatures are in the neighborhood of 300K. For this reason, most thermal IR surveys are performed (8-14)µm.

5- Temperature and Emissivity(ε)

The temperature of an object is obtained by placing a thermometer in direct contact with an object, whereas if the same object measured by a remote sensing radiometer measures the result temperature would be different. [5]

The radiometer measures what is known as the radiant temperature T_{rad} of the body; whereas the thermometer in direct contact measures the kinetic temperature T_{kin} of the body [10]. The kinetic energy of the particles of the body as that random motion causes particles to collide, resulting in changes of energy state (electron) and the emission of electromagnetic radiation. The concentration of the radiant flux of an object is the radiant temperature. Kinetic temperature and radiant temperature are not the same. The radiant temperature is always less than the kinetic temperature because objects do not behave like blackbodies and do not completely obey the Stefan-Boltzman equation. This property of objects is called emissivity(ε) and is defined as the ratio between the radiant flux of the object and the radiant flux of a blackbody with the same (kinetic) temperature [11]**.** The radiant temperature of an object is related to its kinetic temperature by. [9]:

$$T\ (radiant) = \varepsilon^{1/4}\ T\ (kinetic) \ldots\ldots\ldots\ (4)$$

Equation (4) shows that at a given constant T_{kin}, T_{rad} Varies directly with ε.

6- Converting Landsat TM and ETM+ Thermal Bands to Temperature:

The Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors acquire temperature data and store this information as a digital numbers (DN) with a range between 0 and 255. It is possible to convert these DN to degrees in Kelvin using a two step (or optionally Three) process. The first step is to convert the DNs to radiance values using the bias and gain values specific to the individual scene you are working with. An optional second step would apply an atmospheric correction using appropriate local values for several parameters, resulting in more accurate surface temperatures. The final step converts radiance data from step one, or the optional step two, into degrees Kelvin.

6.1. Convert DN to Radiance

For Landsat images that are not in the original USGS “GeoTIFF with Metatdata” format we will need to manually convert these data to radiance. There are two formulas that can be used to convert DN to radiance; each of them depends on the scene calibration data available in the header file or (*.txt) file. The first method uses the Gain and Bias (or Offset) values. The other method uses the Lmin and Lmax spectral radiance scaling factors.

As we mentioned before to calculate the radiance (1st method) we need to get the bias (or offset) and gain values. For Landsat TM and ETM+ images the bias and gain values for the thermal bands will generally be in the header file for the thermal bands. Its important to know remember that the ETM+ sensor has two thermal bands so we may want to convert both the low-gain and high-gain bands to temperature. The formula to convert DN to radiance is:[5]

$$L_{\lambda} = Gain \times DN + Offset \ldots\ldots.(6)$$

Other method (2nd method) by which we convert the Landsat DN to radiance needs to know the Lmin and Lmax bounds of radiance, in order to scale the 255 values in between. We get this radiance range from the *.cpf or *txt files. Each cpf file covers a particular time period of ETM acquisition (usually a couple of months), so it must be chosen the right cpf file.

Example:

GROUP = SCALING_PARAMETERS
GROUP = SCALING_PARAMETERS_LOW
B1L_Lmin_Lmax = (-6.2,293.7)
B2L_Lmin_Lmax = (-6.4,300.9)
B3L_Lmin_Lmax = (-5.0,234.4)
B4L_Lmin_Lmax = (-5.1,241.1)
B5L_Lmin_Lmax = (-1.0,47.57)
B6L_Lmin_Lmax = (0.0,17.04)
B7L_Lmin_Lmax = (-0.35,16.54)
B8L_Lmin_Lmax = (-4.7,243.1)
END_GROUP =
SCALING_PARAMETERS_LOW

So for Band 5, if the scaling parameter is 'LOW' then DN value 0 is equivalent to a radiance of -1, and 255 equals 47.57. Whereas So for Band 6, if the scaling parameter is 'LOW' then DN value 0 is equivalent to a radiance of 0, and 255 equals 17.04. Radiance is in units of watts per meter squared per steradian per micrometer. See Table 1. Lmin is the spectral radiance corresponding to the minimum DN value (usually, a value of 0). Lmax is the radiance corresponding to the maximum DN value (usually, the value of 255). Not only each sensor, but each band within the same sensor, has its own Lmin and Lmax. The formula used in this process is as follows: [12]

$$L_\lambda = [(Lmax_\lambda - Lmin_\lambda) / (QCALmax - QCALmin)] \times (QCAL - QCALmin) + Lmin_\lambda \quad \text{.........(7)}$$

Where:
QCAL: Digital Number
$Lmax_\lambda$: Spectral radiance which is correlate with QCALmax watt/(meter squared.ster.μm)
$Lmin_\lambda$: Spectral radiance which is correlate with QCALmin watt/(meter squared.ster.μm)
QCALmax: Maximum value of QCAL
QCALmin: Minimum value of QCAL, =1 for LPGS, = 0 for NLAPS
L_λ: Spectral radiance

All remote sensing instruments (air borne, and satellite) are designed to record ground information. Most conventional photography records information in the visible part of electromagnetic spectrum. Thermal instruments operate at longer wavelengths. They are designed for detection of radiant temperature [12]. The radiant temperature emitted from the target (a given information about the targets) on the surface is measured by using thermal infrared band 6 (10.4 – 12.5μm) of Landsat 5 TM and Landsat 7 ETM+ images. These information about targets usually scaled and stored as so-called digital numbers that range from 0 to 255. Therefore for most satellites the digital number to be converted to obtain the surface radiant temperature were converted into spectral radiance using the eq (7). Table 1, give the spectral radiance range in W/(m^2.sr.μm) for Landsat ETM+ before and after July 1,2000.

Table1- Spectral Radiance

Band Number	Before July 1, 2000				After July 1, 2000			
	Low Gain		High Gain		Low Gain		High Gain	
	LMIN	LMAX	LMIN	LMAX	LMIN	LMAX	LMIN	LMAX
1	-6.2	297.5	-6.2	194.3	-6.2	293.7	-6.2	191.6
2	-6.0	303.4	-6.0	202.4	-6.4	300.9	-6.4	196.5
3	-4.5	235.5	-4.5	158.6	-5.0	234.4	-5.0	152.9
4	-4.5	235.0	-4.5	157.5	-5.1	241.1	-5.1	157.4
5	-1.0	47.70	-1.0	31.76	-1.0	47.57	-1.0	31.06
6	0.0	17.04	3.2	12.65	0.0	17.04	3.2	12.65
7	-0.35	16.60	-0.35	10.932	-0.35	16.54	-0.35	10.80
8	-5.0	244.00	-5.0	158.40	-4.7	243.1	-4.7	158.3

6.2 Convert the Satellite Radiance to Actual Ground Radiance(Optional)

Converting the at-satellite radiance $R_{satellite}$ to actual ground radiance R_{ground} requires calculating the effects of surface emissivity (ε), atmospheric transmissivity (τ), upwelling radiance (R_u), and reflected radiance (R_r) [12] :

$$R_{ground} = (R_{satelite}\ R_u / \tau\times\varepsilon) - R_r \quad \text{.......(8)}$$

The emissivity of substances can be found in Salisbury and D'Aria (1984). Atmospheric transmissivity and upwelling radiance can be estimated with atmospheric modeling programs like MODTRAN4. Reflected radiance (probably not significant if using ETM Band 6, but will play a role in Band (5 and 7).

Band 61 and 62, as its known, use exactly the same detector (same wavelength and bandwidth) but the gain is set differently (61 is set to 'low' gain, 62 is set to 'high' gain).

6.3 Conversion of the Spectral Radiance to Temperature

The ETM+ thermal band data can be converted from spectral radiance to a more physically useful variable under an assumption of unity emissivity (USGS, 2001).

The formula to convert radiance to temperature without atmospheric correction is:

$$T = k_2 / \ln[(k_1 * \varepsilon / L_\lambda) + 1] \quad \text{........(9)}$$

For atmospherically corrected data the formula to convert radiance to temperature is:

$$T = k_2 / \ln[(k_1 / L_\lambda) + 1] \quad \text{........(10)}$$

Where:

T: Effective at-satellite temperature in Kelvin

K_1: Calibration constant 1 in watts/(meter squared.ster.µm) (666.09) for ETM+ (607.76) for TM

K_2: Calibration constant 2 in K(1282.71) for ETM+(1260.56) for TM

L_λ: Spectral radiance in watts/(meter squared.ster.µm)

τ: Atmospheric transmittance

ε: Spectral emissivity

7- Result, And Discussion

Fig, 4 and 5, show Landsat ETM+ (Effective Temperature) distribution pattern using band 61 for Al_Hammar marsh at different years (2000 and 2003). We chose these dates because the new scene of ETM+ is available with the SLC which permanently turned off, the ETM+ is losing approximately 22% of the data due to the increased scan gap, thus it is required a preprocessing steps in order to overcome the problem. Now, for the surface temperature estimation, we include all proceeding parameters that belongs to ETM+ sensor to convert the measured spectral radiance to the temperature.

The same location and date time (month) was used in order to insure the agreement between those scenes. It should also be know that no atmospheric correction was adopted as a result from the lack in meteorological parameters.

Fig, 6 and 7, show Landsat TM (Effective Temperature) distribution pattern using band 6 for Baghdad capital different years (1990 and 1998). Also, under the same above reason we chose these years but for the surface temperature estimation, we include all parameters that belong to TM sensor from MTL.txt file to convert the measured spectral radiance to the temperature. As we use before, the processed scenes with no atmospheric correction but they have the same coordinate and date of images.

In this paper, the atmospheric transmittance and spectral emissivity are supposed to be 0.95. Therefore the effect by the atmospheric transmittance and spectral emissivity should be considered in the further study.

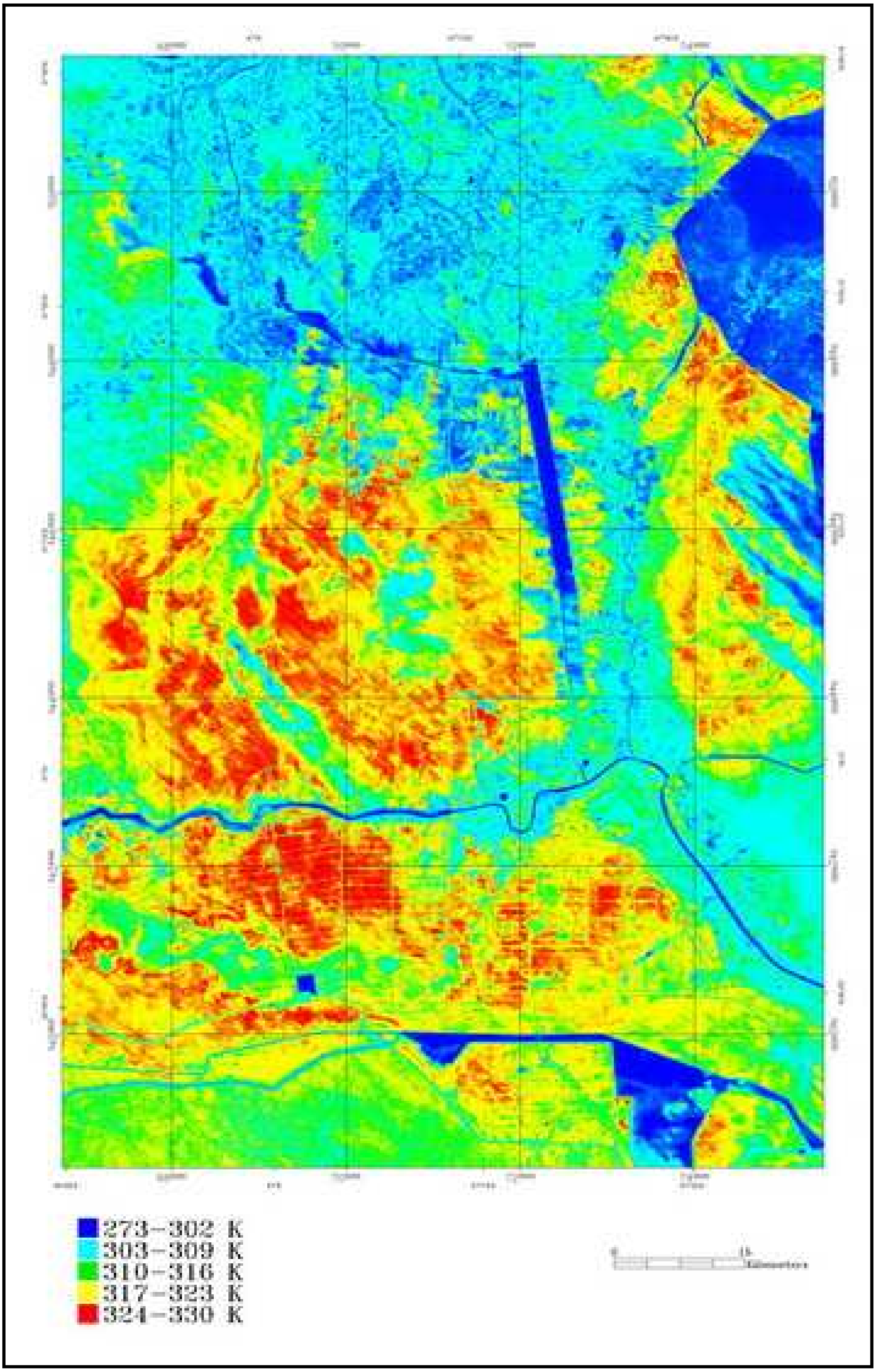


Figure 4- The Thermal Pattern Distribution Map Of Al-Hammar Marsh Area (2000).

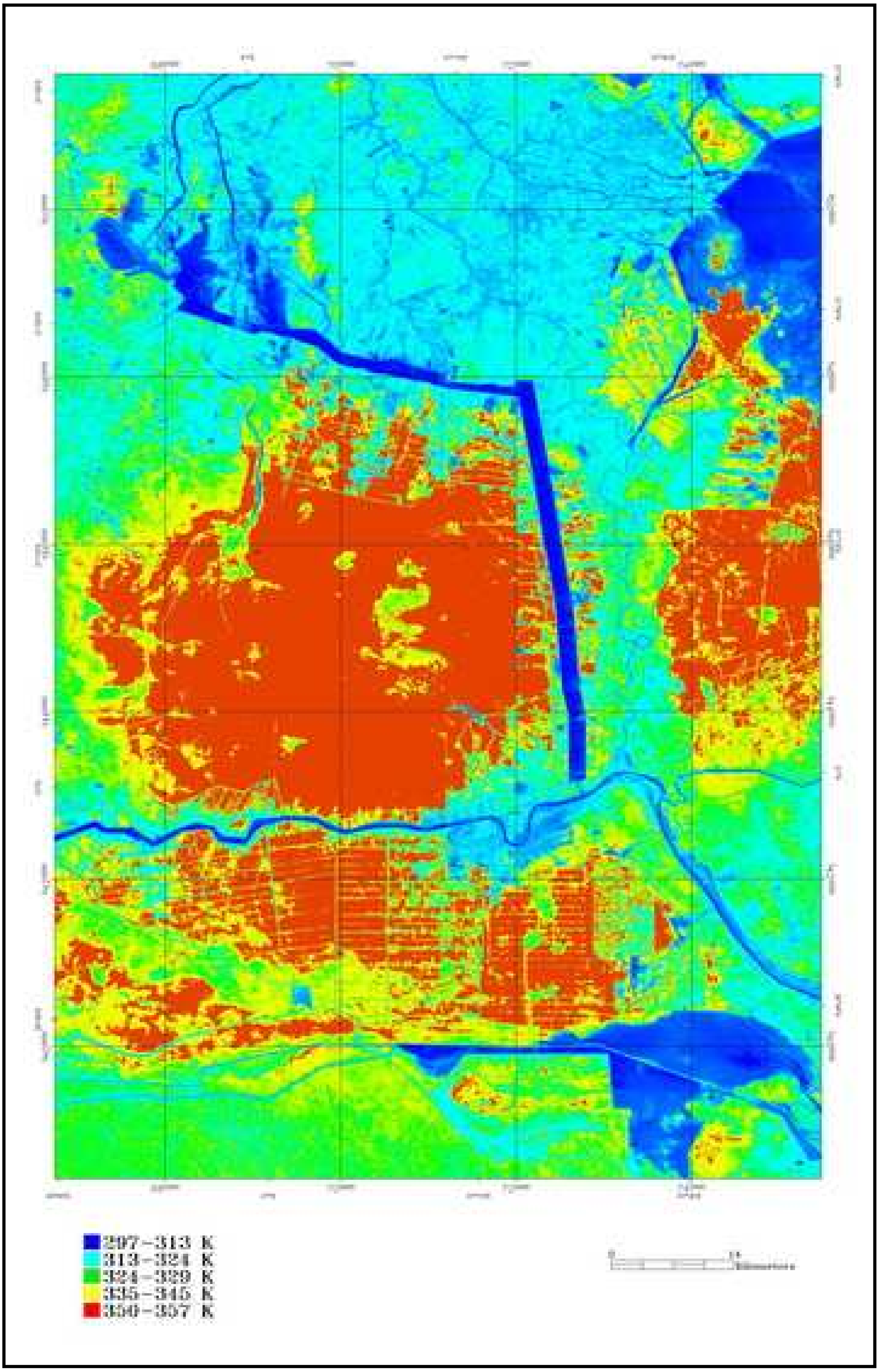


Figure 5- The Thermal Pattern Distribution Map Of Al-Hammar Marsh Area (2003).

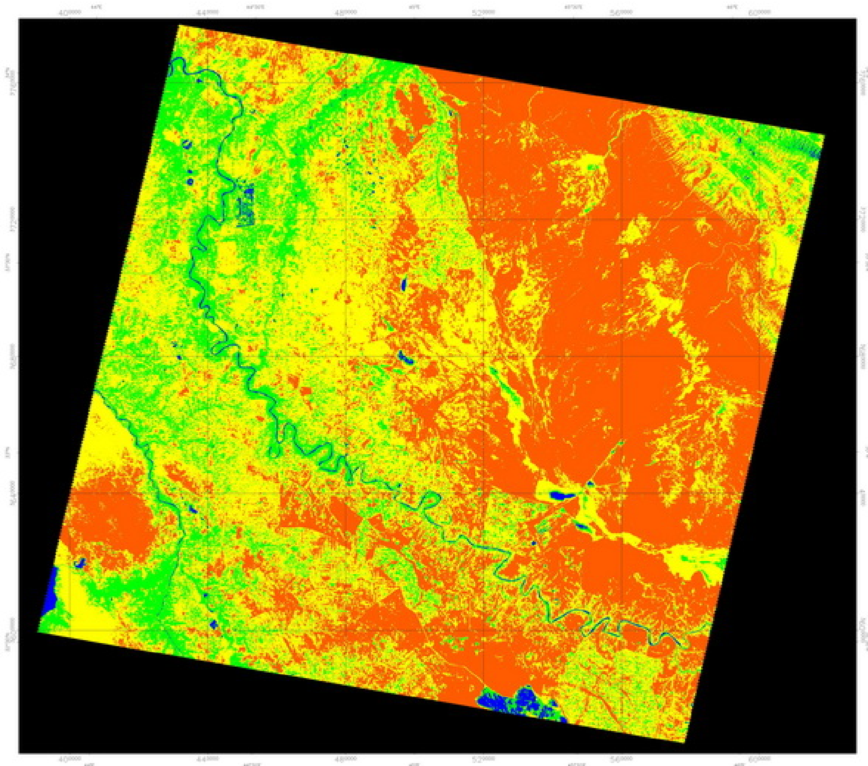


Figure 6- The thermal pattern distribution map of Baghdad (1990).

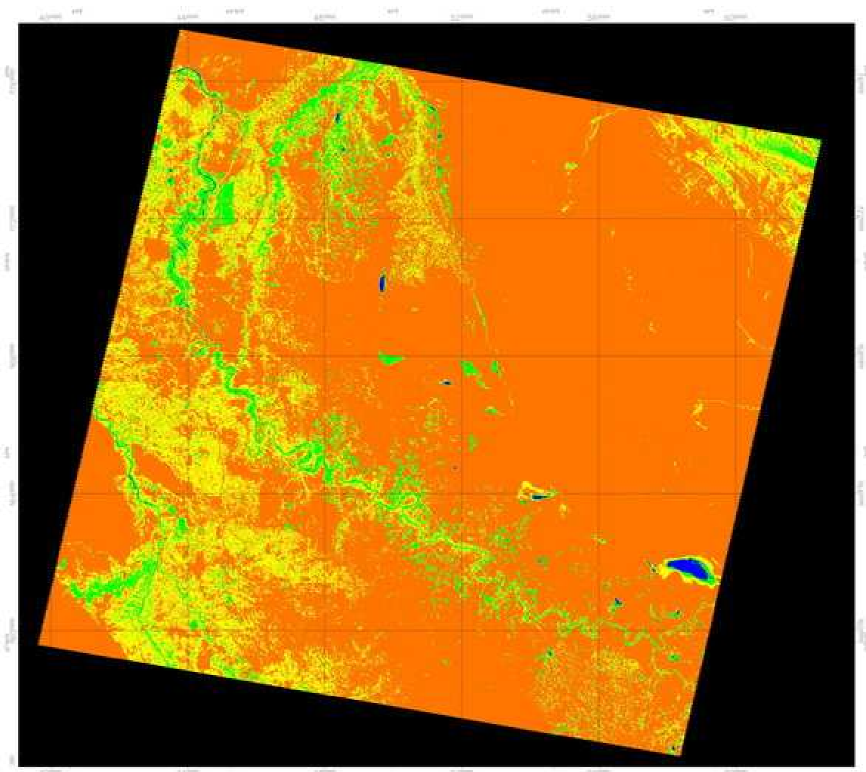
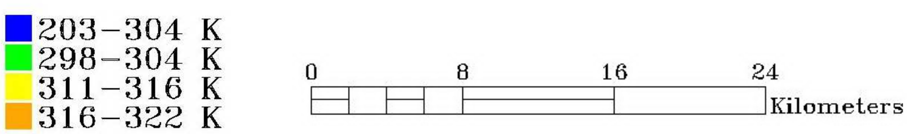


Figure 7- The thermal pattern distribution map of Baghdad (1998).



Conclusion

In this paper, a verification study on the surface temperature derived from LANDSAT 7/ETM+ and LANDSTAT 5/TM data using thermal infrared bands for the estimation of the thermal condition at Al_Hammar marsh and Baghdad capital in Iraq.

The data derived surface temperature provides the low cost by thermal infrared band. Also, the derived surface temperature for different period of time at the same region provides more detailed temperature variations and estimation of the surface temperature.

Thus the results in this paper demonstrate the usefulness of the LANDSAT 7/5 data for mapping the thermal pattern distribution, these results show the obvious increment of the temperature with time evaluation, thus it can be developed as monitoring systems for the environmental issues and the prediction methodologies for the natural disasters.

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