Automatic Surface Temperature Mapping in ArcGIS using Landsat-8 TIRS and ENVI Tools Case Study: Al Habbaniyah Lake

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Abstract

Recently, monitoring environmental conditions and natural resources are the focus of attention of most of engineers and cartographers. Remote sensing satellites have helped the researchers in these tasks. The new instrument which called Thermal Infrared Sensor (TIRS) carried on board of the new generation of Landsat satellites. This instrument captures the temperature of the Earth's surface in two bands, band 10 and band 11. This paper aimed to automate the surface temperature map production for Al Habbaniyah Lake using image processing algorithms and ArcGIS geoprocessing tools. The two bands 10 and 11 of Landsat-8 TIRS data are used in this study. In addition, supervised classification is also used for extracting the boundary of the study area. The results of the presented model showed the ability of ArcGIS software with the integration of ENVI tools on automating complex maps production processes with high accuracy and fast. The study also showed that there is a difference between the temperature values that has calculated from band 10 and band 11. From the resulted maps, the temperature of the NW region of the study area have had the highest temperature values.

Keywords: Al Habbaniyah Lake, Geographic Information System, Landsat 8, TIRS, ENVI, ArcGIS

1. Introduction

Surface Temperature is one of the significant variables that has been measured by remote sensing satellites. These information have a variety of usages in environmental and ecological studies as well as for spatial decision making in GIS. Nowadays, spatial decision making of GIS is widely used in Web-Based GIS applications. It is important for these applications the spatial analysis to be done automatically. The reason why the automation process is important in Web-Based GIS, is actually because that the most of Web GIS applications are used for monitoring purposes in order to make fast and effective decisions.

Monitoring the natural resources is very important for our life in the society. However, in many cases, monitoring tasks are difficult due to the real time information requirement and the automation processes in the client application. The integration of ENVI (image processing software) tools and ArcGIS software makes this task quite easy because of the effective spatial analyst of these software. ENVI uses for image processing such as filtering, enhancing and image classification while ArcGIS is usually used for vector data analysis by a diverse of geoprocessing packages that come with the software.

In this research I used data from Landsat 8 - TIRS to generate the surface temperature map of the Al Habbaniyah Lake located in Anbar, Iraq on the 7th of May, 2014. The data were downloaded using the United States' Geological Survey's (USGS) website. The automation process is done by using supervised classification for extracting the boundary of the lake. Then, the two bands 10 and 11 are used to estimate the temperature value of each pixel in the imagery. Finally, the two features, the boundary and the temperature data are used to generate the final map. All these steps are done automatically by modelling the tools and the equations that I needed in Model Builder in ArcGIS software with ENVI tools.

The reminder of this paper is organized as follows: the study area, LST applications, TIRS, and supervised classification are explained in section 1. The section 2 presented the methodology of the research. In section 3 the results and discussion are illustrated. Finally, in section 4, some conclusions have been drawn from the research results.

1.1. Study Area

The study area of this research is named Al Habbaniyah Lake, is a shallow natural lake in al-Anbar, Iraq, west of Baghdad the capital. It has a surface area of 380km². Traditionally the lake has been used to hold flood water from the River Euphrates, and in 1956 a barrage was constructed at Ramadi for this purpose. The lake was also used for recreational purposes. The lake located specifically between 339895 and 368935 E and between 3671470 and 3700004 N. The figure1 below shows the study area.
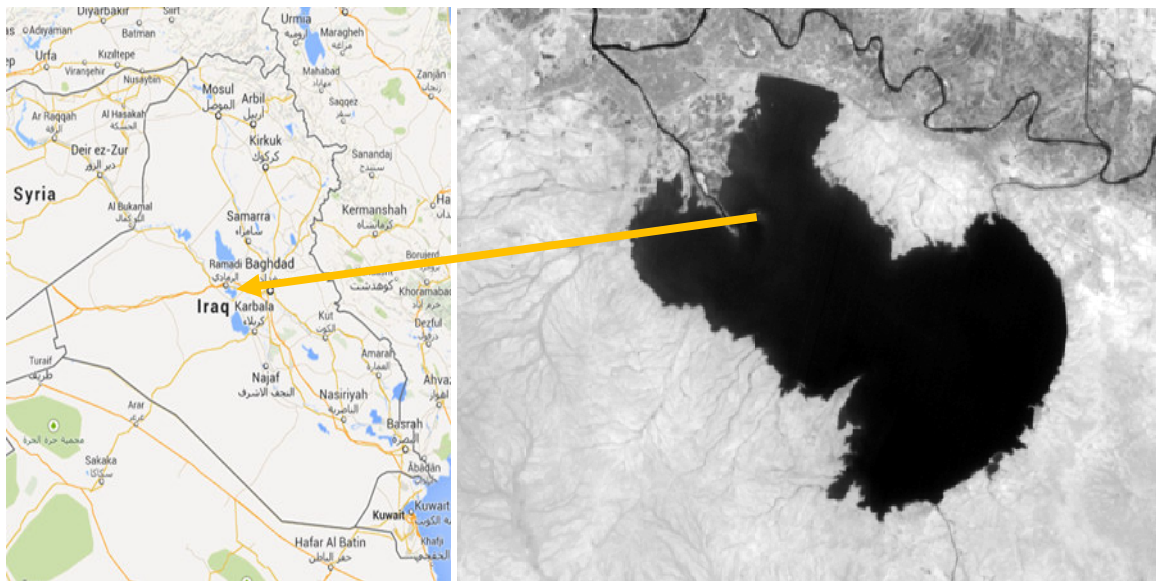
Figure 1. Study Area: Al Habbaniayh Lake
(Source: USGS Website, Google Maps, 2014)

1.2. Land Surface Temperature (LST) Applications

Landsat TIR data have many applications such as monitoring environmental conditions, spatial decision making, and monitor water consumption. Other applications of these data are: examination of urban heat islands, mapping sensible heat flux, volcanic surveillance, and monitoring fire-induced vegetation depletion through burnt area mapping (Kurtis Thome, 2010).Furthermore, TIR imagery plays a critical role in applications such are: detecting tropical forest regeneration, estimating green leaf area index, and estimating regional scale evapotranspiration(Desheng Liu and Xiaolin Zhu,2012).

1.3. Thermal Infrared Sensor (TIRS)

In 2013, the new generation of Landsat series has been lunched which called Landsat Data Continuity Mission (LDCM) or simply Landsat-8. This new generation included the new Thermal Infrared Sensor (TIRS) (Juan C. Jiménez-Muñoz, 2014). The major difference between the new TIRS and the TM/ETM sensors is the existence of two TIR bands in the atmospheric window between 10 and 12 μm (Figure 2). The thermal infrared sensor (TIRS) is a QWIP based instrument envisioned to supplement the Operational Land Imager (OLI) for Landsat -8. This instrument is developed to measure land surface temperature in two thermal bands with a new technology that applies quantum physics to detect heat. The QWIPs TIRS uses are sensitive to two thermal infrared wavelength bands, helping it separate the temperature of the Earth's surface from that of the atmosphere. By this new technology; today, we are able to measure temperature characteristics of the Earth's surface and apply these parameters to variety of applications that help our planet significantly.
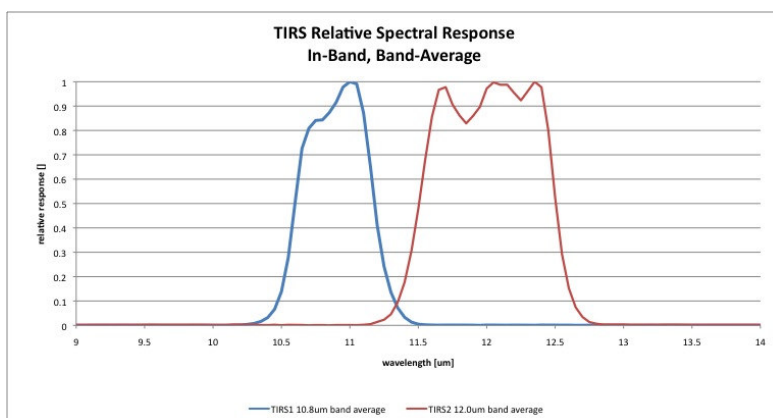

Figure 2. Spectral Response of TIRS

1.4. Supervised Classification

Supervised classification is a technique most often used for the quantitative analysis of remote sensing image data (John A. Richards, 2013). The concept of segmenting the spectral domain into regions is used for this type

of classification. In practice those regions may sometimes overlap. A variety of algorithms is available for the task.

There are many algorithms have been developed for supervised classification such as:

1- Maximum Likelihood Classification.
2- Minimum Distance Classification.
3- Parallelepiped Classification.
4- Mahalanobis Classification.
5- The Spectral Angle Mapper.

In this study, I used Minimum Distance Classification to extract the boundary of the study area. The minimum distance supervised classification technique calculates the mean pixel vector of the feature class. It assigns new pixels to the feature class if the Euclidean distance from that pixel to the mean is less than a user-defined threshold, or to non-feature otherwise (Neal R. Harvey, 2001).

2. The methodology

The methodology of this research is divided into three main parts: original DN of the TIRS to temperature value conversion, study area boundary extraction using supervised classification and building a model for automatic mapping. This section will present these three parts.

2.1 Temperature Values Calculations

First of all, we need to convert the original DNs of TIRS into Top of Atmospheric Radiance (TOAr).Therefore, the original digital numbers (DN) of Landsat 8 TIR bands are converted into radiance based on the methods provided by Chander and Markham (2003) and the Landsat 7 Science Data Users Handbook (2006). The following equation 1 is used to convert original DNs into TOAr as shown below:

$$\textbf{TOAr = M * DN+B} \qquad \text{(eq.1)}$$

Where: M is the Radiance Multiplier

B is the Radiance Add

The M, B values are in the metadata file of Landsat 8 data. Table 1 below shows the parameters that we need for this task.

Table 1. The metadata of Landsat 8- TIR

	Band 10	Band 11
Radiance Multiplier(M)	0.0003342	0.0003342
Radiance Add(B)	0.1	0.1
K1	774.89	480.89
K2	1321.08	1201.14

Where: K1 and K2 are parameters of band-specific thermal conversion constant.

After we have got the TOAr values, now we are able to calculate brightness temperature (Filiz Bektaş Balçik, 2013) using the equation 2 below:

$$Tkelvin = \frac{K2}{ln\left(\frac{K1}{TOAr} + 1\right)} \qquad \text{(eq.2)}$$

By using K1 and K2 parameters, we have converted the TOAr values into temperature in degrees kelvin.

After this stage, we need to convert the unit of the temperature values into Fahrenheit or Celsius. This can be done by subtracting 273.15 from the degrees kelvin. For Fahrenheit, multiply the degrees Celsius by 1.8 and then add 32. We can do this as one step.

Now, we need to apply all these steps in ArcGIS using Model Builder and Raster Calculator function. The result of the model is shown in the diagram below:
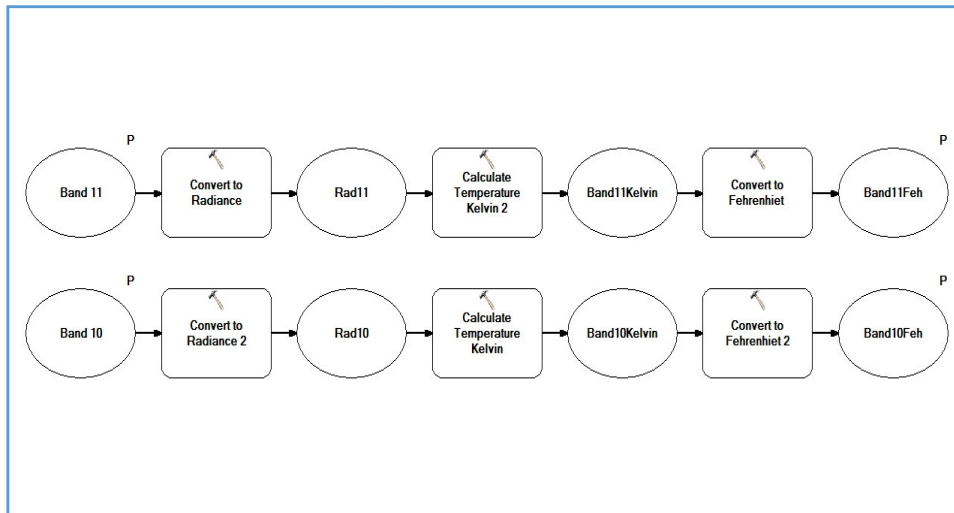
Diagram 1. The Model of Temperature Calculator in ArcGIS

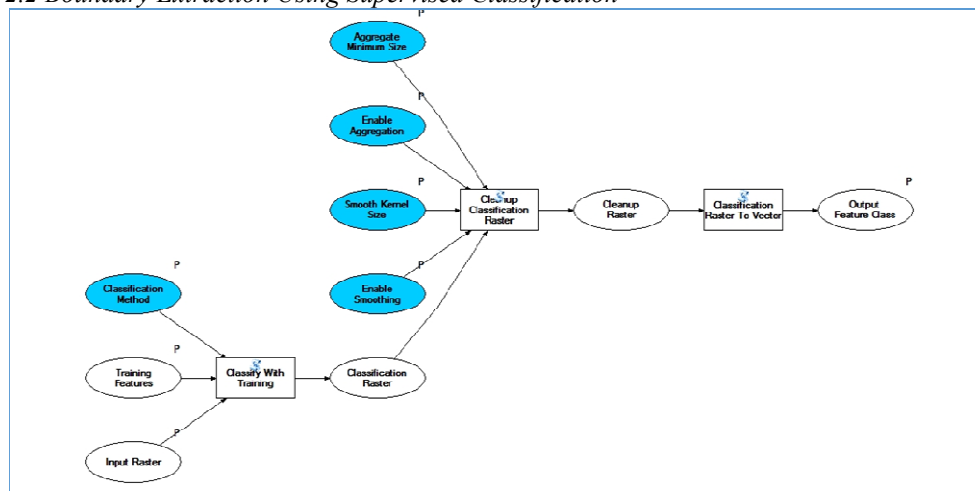*2.2 Boundary Extraction Using Supervised Classification*

Diagram 2. The Model of Supervised Classification in ArcGIS

In this stage, I used ENVI tools inside ArcGIS in order to classify the TIR image. The process used two polygon as a training sample area in order to classify the image into two main classes, water bodies and other lands cover. Then, the training samples are applied to perform the Minimum Distance Classification. After that, the median filter is used in order to remove any noises from the raster layer. Finally, the layer is converted into vector format to be used later for extracting the boundary of the lake. The model is shown in the diagram 2 below:

2.3 Final Model with Boundary Extraction

In this last step, the two models that I have discussed before are combined into one model in order to generate the final layers in one run. The condition statements are used in order to extract the boundary layer depending on the class name and the area of the polygon. The model finally is able to generate the temperature maps for Landsat 8 raw data specifically from the two thermal bands 10 and 11. The complete model is shown in the diagram 3 below:
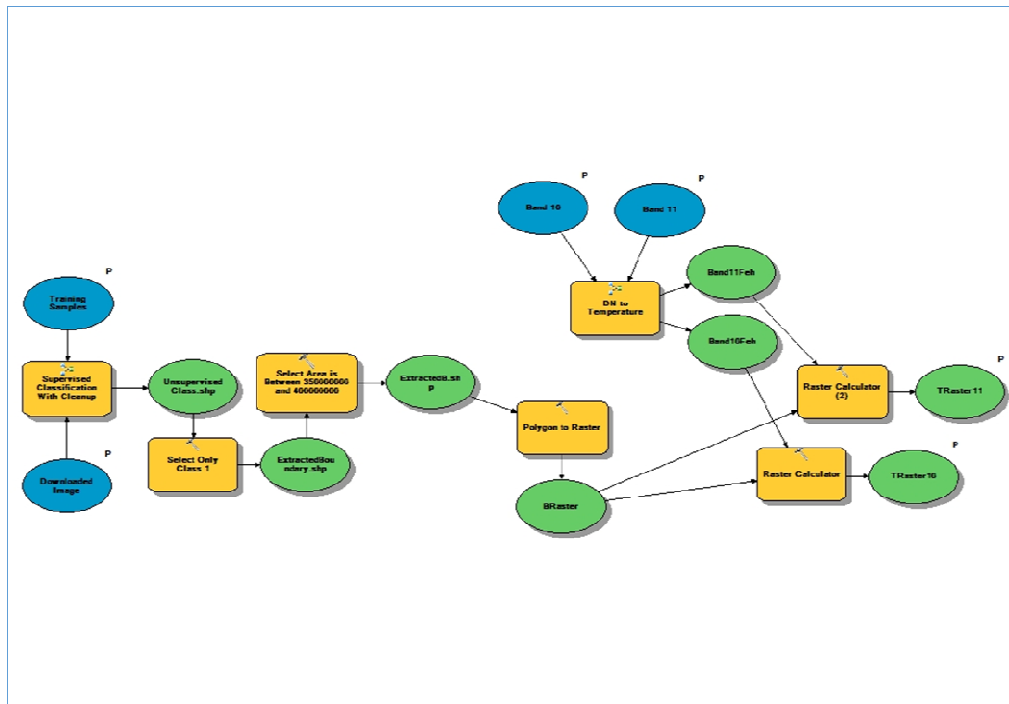
Diagram 3. The Final Model of Automatic Surface Temperature Mapping

3. Results and Discussion

The integration of ArcGIS and ENVI software showed that this integration is important process for remote sensing applications. This is because the two software have the ability on image processing and vector data processing and they have advanced tools that can deal with different kind of data sources. The model that generated using tools of ArcGIS and ENVI has showed its effectiveness and the ability on generating temperature maps for the Al-habbaniyah Lake automatically. The most surprising thing it was the accuracy that I have got for the boundary extraction from the supervised classification it was great. Also the flexibility of both software is helped for calculating different kinds of equations.

The results that I have got from Landsat 8 thermal bands and the model was measurable because the hot weather in Iraq at that session. So the range of temperature values that were generated started from 52 to 63 it was reliable. However, the accuracy assessment is done by comparing the results with the measurements of Iraq weather monitoring stations at that area. The overall accuracy with average RMSE=5 Degrees Celsius was acceptable because of the fact that the temperature values of Landsat TIRS is higher than the real temperature values and this is because of the TIRS does not measure the temperature of the air like weather stations do.

The temperature values in the NW direction of the study area were higher than the other parts of the region. Actually, this is because those areas are expanded nearly after 2011. Before 2011 it was land area, therefore, it is reliable because of the depth of water is less in those areas. Finally, at the boundaries the temperature was higher this is because of the fact that the temperature of the land area are higher than of water bodies. The figure 3 and figure 4 show the results of the model.
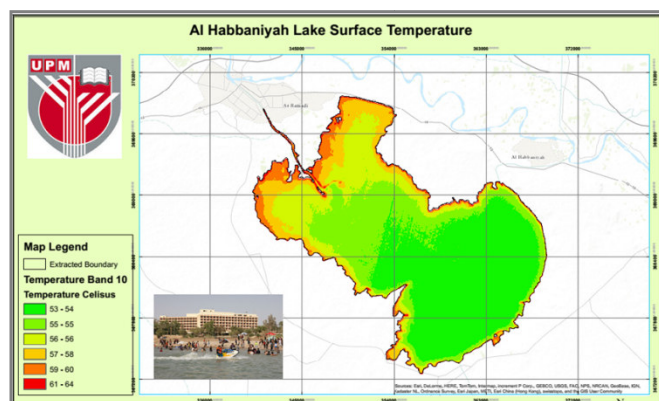

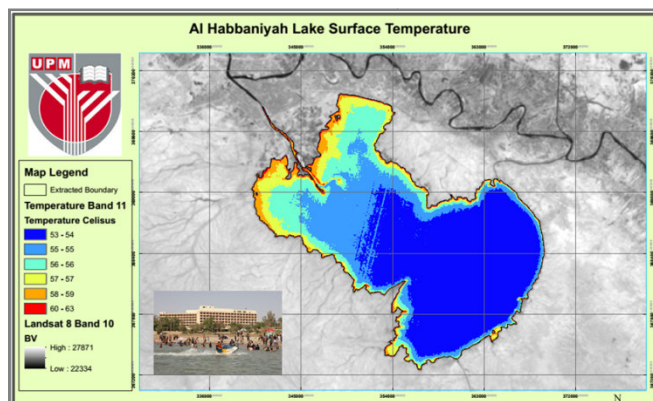Figure 3. Band 10: Al Habbaniyah Lake Surface Temperature

Figure 4. Band 11: Al Habbaniyah Lake Surface Temperature

5. Conclusion

This research analysed TIRS data and developed a model for automatic surface temperature mapping. The integration of ArcGIS and ENVI software have given the opportunities for advanced spatial analysis. In the presented project, the ability of two software has been proven when the result of the model that developed it was reliable and enough accurate. Furthermore, the process is takes only 2-3 minutes in order to generate temperature maps for Landsat 8 raw data using supervised classification, median filtering and other important tools related to vector data analysis. Also, the layout of the generated data created using ArcGIS and it showed the effective ability for creating layouts for the extraction information from different kinds of analysis. Finally, it can be concluded that the integration of ArcGIS and ENVI will grow the remote sensing and image processing science faster and more affectively.

6. Acknowledgment

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