Combination of visible and thermal remotely sensed data for enhancement of Land Cover Classification by using satellite imagery

Aysar Jameel Abdalkadhum\textsuperscript{1,4}, Mohammad Mejbel Salih\textsuperscript{2} and Oday Zakariya Jasim\textsuperscript{3}

\textsuperscript{1,2,3} Department of civil Engineering, University of Technology- Baghdad/Iraq
\textsuperscript{4} Department of Hydraulic Structures Engineering, Water Resources Engineering Faculty, Al-Qasim Green University-Babylon/Iraq.

Email: Aysar@wrec.uoqasim.edu.iq

Abstract. On a large scale, the land cover classification has been investigated throughout the world in remote sensing for different kinds of applications such as water resources, agricultural, environmental, as well as ecological and hydrological applications. In order enhance accuracy of the classification results, Landsat and multispectral bands are used to study the numerous classification methods. Remote sensing thermal data provides valuable information in order to examine the effectiveness of applying the thermal bands to extract useful land cover thematic maps. In this research, Landsat-8 satellite data captured by Operational Land Imager (OLI) and the Thermal Infrared (TIRS) Sensors, with using remotely sensing data and Geographic Information System (GIS) analysis with using ground truth data collect from fieldwork in same time of imagery capturing by using infrared thermometer camera. In 2018, single date Landsat-8 image of the study area in Iraq was captured in winter. This image is used to estimate Land Surface Temperature (LST) by split window algorithm and performing Land Cover (LC) classification after image noise removal by using supervised classification algorithms Support Vector Machine (SVM) with multi-spectral and thermal bands combinations to find out which one has more accuracy. Result shows the effective and efficiency of the proposed method compared by traditional classification methods. The overall accuracy and Kappa coefficient are 94.25\%, 64.43\% and 0.93, 0.63, respectively.

Keyword:
Land cover classification; SVM algorithm; Infrared Thermometer Camera; Thermal remote sensing; combination bands.

1. Introduction
Land Use Land Cover (LULC) dynamics serves as an essential parameter in current policies and strategies for monitoring and natural resource management. Information of land cover is an essential variable for a lot of climate and hydrological studies. Usually land cover properties human and physical environments, furthermore decisions can be made to affect many environmental variables [1], including roughness of surface, moisture availability, albedo, mechanisms for runoff generation [2] and water quality [3]. Then, land cover mapping becomes necessary and accurate for modelling and conception of these bio geophysical characteristics of the land surfaces. Presently, the world has attended the importance of land use land cover changes in modifications of environmental that can lead to adverse effects in world [4]. The land cover land use changes indicated to environmental...
changes lead around by natural or human consequences [5]. This provides an important aspect in assessment, monitoring and protecting Earth’s resources that is wanted for sustainable development and economic proliferation of an area [6]. With the development of integrated geospatial techniques which integrate the use of Global Positioning System (GPS), Remote Sensing (RS), and Geographic Information Systems (GIS) the calculation of spatiotemporal of land cover land use has becomes, fast, facile, low fee and more precise [5]. Image processing on multi-spectral satellite imagery and multi-temporal has great potential in land cover classification and analyses of change detection. Land surface temperature (LST) determined from the thermal remotely sensed data shows unique response to land cover changes [7; 8; 9]. Therefore, thermal infrared (TIR) sensors can estimate information of land surface temperature across different land cover classes [10]. For instance, estimated the distinguish of wetlands with the bands 2 to 5 of the single date and Landsat 5 images with multi temporal. The overall accuracy was 69% of the single date image compared with 88% from the two date images with an impotent increase in the Kappa test statistics [11]. Maxwell et al. [12] introduced an automated technique for classification of four land cover types using only the bands 2 and 4 from Landsat MSS with 92.2% overall accuracy. Langley et al. [13] differentiate the single date Landsat TM image and multi-temporal images for classification of the land cover with the bands 3 to 5 of Landsat TM images. They concluded that the single-date image may provide a reliable vegetation cover map in semi-arid environments but the multi-temporal images have improved the accuracies of some landscapes. While the thermal band of the spatial resolution is more rough if compared to the visible bands of the same satellite, the remotely sensing thermal data may contain useful information related to the spatial variance of land surface and therefore vegetation properties [14], which has so far not been explored to the full extent. The objective of this research is to investigate the value and effectiveness of the thermal remote sensing data to improving land cover classification. The region of study is the Al-Hashimiya district in Babylon/Iraq providing with a variety of land cover types, mainly including crop land, agriculture land, water body, rivers, roads and residential area.

2. Area of Study
The study area of Al-Hashimiya district is located in the middle part in Iraq as shown in figure 1. The study area covers a whole area of the district 1836.74 square kilometers (183674.166 hectares). The main land cover types consist of crop land, agriculture land, water body, rivers, roads and residential area. The climate is temperate, therefore, the mean monthly temperatures range from a maximum of about 38 °C in July and a minimum of 12 °C in January. The evapotranspiration is high in summer for interval from July to August, and the mean annual precipitation of 71 mm in February according to the monthly climate data that were collected from Meteorological Organization and Seismology in Iraq (2018).
Figure 1. Illustration of the Al-Hashimiya district is located in the middle part in Iraq in the left, and layer study area in right with a Landsat-8 image captured on 31st December.

3. Satellite Data
The Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), which were launched (on 11 February 2013), provide nine spectral bands and two thermal bands. All spectral bands are collected at 30 m, except for the thermal bands that are captured at 100 m resolution and resampled to 30 m in the delivered product and the panchromatic band 8 providing 15 m data. One cloud-free Landsat-8 image was acquired for 31st December 2018 (at the same time the ground-truth field campaign was conducted to observation land temperature with connected to the surface by using Infrared Thermometer Camera), only one Landsat 8 image from 31st December 2018 was tested to explore the effectiveness of single image land cover classification based on thermal data.

4. Methodology
An illustrated methodology is applied in this paper is illustrated in Figure 2. The thermal data from TIRS bands 10 and 11 of Landsat-8 are affected strongly by the energy out of the field (stray light) especially the band 11 [15]. Therefore, the first, the raw data of single date Landsat-8 (OLI&TIRS) remote sensing imagery are used to carry out some processes by using band-10 to estimate land surface temperature. Second, to carry out equations of land surface temperature a spectral indices are applied, using infrared thermometer camera to collect surface temperature directly at the same time satellite data acquired on 31st December 2018 to validate the LST estimation. Third, band combination using (band-1, band-10 and band-2) and comparison then with RBG image. There are several methods of estimating and calculating land surface temperature (LST), different algorithms to do that like Split-Window (SW), Dual-Angle (DA), and Single-Channel (SC). In this research we will use the Split-Window, the thermal band-10 and NDVI, which are acquired for the study area [16]. The LST equation is:

\[ \text{LST} = \frac{BT}{[1 + \left( \frac{1}{\rho} \right) \varepsilon \lambda / \text{LSE}]} \]

(1)

Where BT represent Brightness Temperature, \( \lambda \text{BT} \) Wavelength of the band, \( \varepsilon \lambda / \text{LSE} \): Land Surface Emissivity and \( \rho \) is equal to 1438.

Brightness temperature is a blackbody temperature, which is used to produce the radiance perceived by the sensor, according to NASA 2012 [17]. Moreover, it is the temperature that has been received by the satellite at the time when the image was taken. Hence, it’s not the real ground temperature; this represents the temperature at satellite [19]. TIRS bands data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file, the brightness temperature equation, which is used to convert from spectral radiance to brightness temperature is:

\[ \text{BT} = \frac{K_2}{1 + \left( \frac{1}{\rho} \right) K_1} - 273.15 \]

(2)

Where \( K_1 \) and \( K_2 \) represent thermal constants of the thermal bands in this study used only band 10. Therefore, Landsat-8 provides some constants to estimate LST such as thermal constant and rescaling factor; which is found it in metadata file of Landsat satellite images (Table 1), \( L_\lambda \) represented Top of Atmospheric spectral radiance (TOA).

| Table 1. | K_1 and K_2 and Rescaling factor values from metadata file |
|---------|---------------------------------------------------------|
| Thermal Constant | Band (10) |
| K_1       | 1321.08     |
Now, to find the Brightness Temperature (BT), the Top Of Atmospheric spectral radiance (TOA) is acquired. Equation (3) used that:

\[ L_{\lambda} = M_L Q_{cal} + A_L \]  

(3)

Where ML refers to the band specific multiplicative rescaling factor (radiance_mult_band_10), AL represents Band specific additive rescaling factor (radiance_add_band_10) and Qcal as band 10 image.

---

**Figure 2.** A flow chart illustrating the research methodology.

Land surface emissivity factor is used to estimate blackbody radiance that is measured from land surface temperature, relatively [18]. There are several methods used to estimate land surface emissivity like equation (4). One of these is the Normalized Difference Vegetation Index (NDVI)
method, taking into account the proportion vegetation (PV), then LST in Celsius is determined. The formula of land surface emissivity is used in equation (5).

\[ \varepsilon = \varepsilon_{S\lambda} \cdot P_V + \varepsilon_{V\lambda} \cdot (1 - P_V) + C_\lambda \]  \hspace{1cm} (4)

\[ PV = \frac{(NDVI_1 - NDVI_2)}{NDVI_1 + NDVI_2} \]  \hspace{1cm} (5)

Where \( \varepsilon = \) Land Surface Emissivity, \( \varepsilon_{S\lambda} = \) soil emissivity, \( \varepsilon_{V\lambda} = \) vegetation emissivity

\( PV = \) proportion of vegetation and \( C_\lambda = \) surface roughness taken as a constant value of 0.009.

5. Image Classification

Supervised classification (support vector machine (SVM)) was used to produce land cover thematic map, which is considered most common technique of classification approaches [19]. These techniques are required to define the training samples for each class and creating a spectral signature where 50 points of them were samples. Single pixel approach was used to take samples. Wherefore, medium accuracy of the satellite will allow the use of this approach to collect samples[20].

6. Accuracy Assessment

The accuracy assessments provide most information on where the errors of classification occurred. To know how much a classification is accurate, a set of random points must be created to estimate the data, at the location of each random point. The result would be finding the type of land cover of that spot using (truth points) and comparing it to land cover of the classified raster [21]. To estimate the accuracy of the classification, three standard criteria were used (overall accuracy, producer’s accuracy and user’s accuracy) [22].

7. Result and Discussion

Figure 3 shows the LST of Al-Hashimiya city using the digital image processing on the thermal band 10 from Landsat satellite image. The temperate in the LST is divided into five classes as indicated in figure below.

The land cover classification in this study is based on a single date image, which was carried out with the Landsat-8 image in 31 December 2018. As detailed in Section 3, two variants with different bands combination were considered and classified into the eight land cover class using the SVM algorithm. The classification is performed in two methods, the first method by choosing the SVM algorithm to classify the image of the study area by using the visible bands and the thematic map of this classification is shown in Figure 4 below. From selecting testing sites we perform the accuracy assessment for our classification and we find the overall accuracy = 64.43% and kappa coefficient = 0.63. On other hand, we perform the second classification also by using SVM algorithm. However, we intend to do bands combination of the same image by selecting band1, band 10 and band2. Figure 5 illustrates the land cover thematic map with the best overall accuracy =94.25% and kappa coefficient = 0.93 among all the variants for each category. The consistent patterns can be visually observed in the agriculture land and urban areas, meanwhile the roads and highways in the middle part of the study area are clearly distinguished. The agricultural areas were classified in more detail based on the ground truth data. The major cropland (wheat and barley) and the oldest plants areas have been well recognized but misclassification still exists, especially between the different crops. Table 4 indicates the overall accuracy and Kappa coefficient for the two methods of classifications.
Figure 3. The LST thematic map of Al-Hashimiya city.

Figure 4. Classification image by SVM algorithm based on RGB image.
Figure 5. Image classification with eight class by SVM algorithm based on thermal band-10 and two visible bands combination of the Landsat-8 image.

Table 2. The overall accuracy and kappa coefficient of the two methods

|                     | Traditional classification | The proposed method |
|---------------------|---------------------------|---------------------|
| overall accuracy    | 64.43%                    | 94.25%              |
| Kappa coefficient   | 0.63                      | 0.93                |

8. Conclusion
The proposed method is performed by comparing two methods of image classification. The first method is performed by using the visible bands of the satellite image. However, the second method conducted by combining the visible and thermal bands of Landsat-8 satellite data captured by Operational Land Imager (OLI) and the Thermal Infrared (TIRS) Sensors, by using remote sensing and geographic information system (GIS) analysis with the help of ground truth data collected from fieldwork in the same time of image capturing by using infrared thermometer camera. In addition to the LST thematic map, that classification come out the combining visible and thermal bands that were obtained from Landsat satellite. Regarding the results obtained it may be concluded that the effectiveness of combination bands between thermal and visible bands for LC classification is highly recommended but is dependent on LC class types. So, the result was concluded that thermal bands play a good role in the extraction of LC thematic maps.

9. Acknowledgments
The researchers would like to sincerely thank the United States Geological Survey (USGS) for providing the Landsat image. The researchers are also grateful to Meteorological Organization and Seismology report in Iraq for providing meteorological data and all the reviewers for their valuable comments and suggestions.
10. References

[1] Bounoua L, DeFries R, Collatz G J, Sellers P and Khan H 2002 Effects of land cover conversion on surface climate. Climatic Change, 52, pp 29–64
[2] Dickinson R E 1995 Land processes in climate models Remote Sens. Environ. 51, pp 27-38
[3] Nilsson C, Pizzuto J E, Moglen G E, Palmer M A, Stanley E H, Bockstael N E and Thompson L C 2002 Ecological forecasting and the urbanization of stream ecosystems: Challenges for economists, hydrologists, geomorphologists, and ecologists. Ecosystems, 6, pp 659–674
[4] Iqbal M F and Khan I A 2014 Spatiotemporal land use land cover change analysis and erosion risk mapping of Azad Jammu and Kashmir, Pakistan. Egypt. J. Remote Sens. Space Sci. 17, pp 209–229
[5] Rawat J S and Kumar M 2015 Monitoring land use/cover change using remote sensing and GIS techniques: a case study of Hawalbagh block, district Almora, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci. 18 pp 77–84
[6] Rawat J S, Biswas V and Kumar M 2013 Changes in land use/cover using geospatial techniques: a case study of Ramnagar town area, district Nainital, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci. 16 pp 111–117, 2013a
[7] Weng Q, Lu D and Schubring J 2004 Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. Remote Sens. Environ. 89, pp 467–483
[8] Settur B, Rajan K S and Ramachandra T V 2013 Land surface temperature responses to land use land cover dynamics. Geoinfor. Geostat. 1 (4)
[9] Muhammad Mejbel Salih, Oday Zakariya Jasim, Khalid I. Hassoon and Aysar Jameel Abdalkadhum 2018 Land Surface Temperature Retrieval from LANDSAT-8 Thermal Infrared Sensor Data and validation with Infrared Thermometer Camera. International Journal of Engineering and Technology, 7(4.20) pp 608-612
[10] Sinha S, Pandey P C, Sharma L K, Nathawat M S, Kumar P and Kanga S 2014 Remote estimation of land surface temperature for different LULC features of a moist deciduous tropical forest region. In: Srivastava, P.K., Mukherjee, S., Gupta, M., Islam, T. (Eds.), In: Remote Sensing Applications in Environmental Research (Part 1) Springer International Publishing, Switzerland
[11] Lunetta R S and Balogh M E 1999 Application of multi-temporal Landsat 5 TM imagery for wetland identification. Photogramm. Eng. Remote Sens. 65, pp 1303–1310
[12] Maxwell S K, Nuckols J R, Ward M H and Hoffer R M 2004 An automated approach to mapping corn from Landsat imagery. Comput. Electron. Agric. 43, pp 43–54
[13] Langley S K, Cheshire H M and Humes K S 2001 A comparison of single date and multi-temporal satellite image classifications in a semi-arid grassland. J. Arid. Environ. 49, pp 401–411
[14] DeFries R S and Hansen M C 2000 Townshend, J R G, Global continuous fields of vegetation characteristics: A linear mixture model applied to multi-year 8 km AVHRR data. Int. J. Remote Sens. 21, pp 1389–1414
[15] J Barsi, J Schott, S Hook, N Raqueno, B Markham and R Radocinski 2014 Landsat-8 Thermal Infrared Sensor (TIRS) Vicarious Radiometric Calibration. Remote Sensing, vol. 6, pp. pp 11607-11626
[16] Rajeshwari A and Mani N D Estimation of land surface temperature of Dindigul District using Landsat 8 Data. International Journal of Research in Engineering and Technology, 3, 2319-1163.
[17] NASA 2012 National Aeronautics and Space Administration. Goddard Earth Sciences (GES) Data and Information Services Center (DISC).
[18] Sobrino J A, Jiménez-Muñoz J C, Sòria G, Romaguera M, Guanter L, Moreno J, Plaza A and Martínez P 2008 Land Surface Emissivity Retrieval from Different VNIR and TIR Sensors. IEEE Transactions on Geoscience and Remote Sensing, 46, 316-327
[19] Gillespie A 2014 Land Surface Emissivity. In: Njoku, E.G., Ed., Encyclopedia of Earth Sciences Series—Encyclopedia of Remote Sensing, Springer, New York
[20] Russell G Congalton and Kass Green 2009 Assessing the accuracy of remotely sensed data principles and practices, by Taylor & Francis Group, LLC. p 70
[21] Jensen J R 2016 Introductory Digital Image Processing: A Remote Sensing Perspective. No. Ed. 4, Prentice-Hall Inc., Upper Saddle River
[22] Lillesand T, Kiefer R W and Chipman J 2014 Remote Sensing and Image Interpretation. John Wiley & Sons, Hoboken