The Effects of Land Cover Changes on Land Surface Temperature in Amman; an Urban Climate Change Study

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ABSTRACT

In this study, remote sensing techniques were used to examine the relationship between land cover change and land surface temperature in Amman city (the area of study). Landsat TM5 datasets for the years 1987 and 2003 , landsat 8 for the year 2014 were used in the analysis using PCI Geomatica 9.1 to perform supervised classification, MS Excel to calculate the changes in areas, ENVI 4.5 to perform land surface temperature estimation and ArcGIS 9.3 for overlap analysis of the results.

Four classes were classified within the study area: Built-up area, Vacant Land, Vegetation and Quarries & Restructured Areas. An accuracy assessment was conducted for each data set and the statistics show that the overall accuracies are 92% and 86% and 88%, and the overall Kappa statistics were 0.872 % and 0.783% and 0.823 for the images of 1987 and 2003 and 2014, respectively. The overall land surface temperature ranged from 19°C to 29°C with a mean of 23.9°C and with a standard deviation of 3.0°C for the 1987 image and it ranged from 20°C to 32°C with a mean of 26.2°C and with a standard deviation of 4.1°C for the 2003 image. where it ranged from 20°C to 33°C with a mean of 26.5°C and with a standard deviation of 4.4°C for the 2014 image. The overall mean temperature was also increased by 3.2°C. LST values were increased for each land cover type in the 2014 image compared to the 1987 image, except for the Vegetation. The mean of temperature values for the built up area was increased by 4°C, and by 1.7 °C for Vacant Land and by 0.1°C for Quarries & Restructured Areas. . The mean for temperature values for the Vegetation areas were decreased by -1.7°C. These results showed strong evidence and relationship between the changes of land cover types on the local temperature of the city.

Keywords: The Change, Land Cover, Temperature.

Introduction

Changes in land cover have become one of the most important topics in current research to manage natural resources and to monitor environmental changes. These changes are mostly associated with accelerated economic growth in an urbanizing environment (Jonathan et al., 2005; Ifatimehin, 2007). One of the most significant changes is the difference between thermal properties of the radiating surface. The thermal properties of built-up land, soil and impervious surfaces result in more solar energy being stored and converted to sensible heat, and the removal of shrubs and trees reduces the natural cooling effects of shading and evapotranspiration (Pickett et al., 2001).

Remote sensing techniques provide data and tools for advanced ecosystem management and monitoring which lead to the possibility of detecting changes of land cover patterns (Abd El-Kawy et al., 2011; Abbas et al, 2010; Peijun et al, 2010; Dewan and Yamaguchi, 2009; Andreas and Hugh, 2009) and also the possibility to estimate land surface temperature (Liano and Shi, 2009; Kustas and Anderson, 2009; Ifatimehin, 2008). Thus, it provides capability for studying the effects of land cover changes on land surface temperature (Jing Jiang, Guangjin Tian,2010; Ifatimehin et al, 2009; Xiao-Ling Chen et al, 2006)

NASA creates two models to calibrate surface temperature from the digital numbers (DNs) of Landsat TM data: the first converts DNs to radiance while the second converts radiance to absolute temperature. These two models are based on the thermal band (band6), which is used in estimating land surface temperature, while other bands can be used to extract land cover patterns. This study is an attempt to analyze the effects of land

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cover changes on land surface temperature using thermal remotely sensed data

Problem Statement

Due to fast growing of populations, changes in land cover patterns occur mostly in built up areas, which not only affects land surface temperature at local scales but also contributes to global temperature change. From this point, the importance of studying land cover pattern changes is evident.

In this study, remote sensing techniques were used to examine the relationship between land cover changes and land surface temperature by taking Amman city (the capital of Jordan) as the area of study. This mission will be implemented based on the following research question: How do land cover changes affect land surface temperature?

Aim and objectives

The main aim of this research is to study the effects of land cover changes on land surface temperature by using thermal remotely sensed data. The specific objectives are:

- To detect land cover changes in Amman city between 1987 and 2014.
- To estimate land surface temperature of each land cover type in Amman city between 1987 and 2014
- To study the effects of land cover changes on land surface temperatures of the city.

Materials and Software

Landsat TM5 datasets for the years 1987 and 2003 and Landsat 8 for the year 2014 were used in the analysis (see Table 1). The data was analysed using PCI Geomatica9.1 to perform supervised classification, MS Excel to calculate the changes in the areas, ENVI4.5 to perform land surface temperature estimation and ArcGIS9.3 for overlap analysis of the results.

Area of Study

Amman city, the capital of Jordan, was chosen as an area for this study (see Figure 1). It is located at latitude 31°56′59″N and longitude 35°55′58″E, with a total area of about 1680 km^2. It is the country's political, cultural and commercial centre. The city was originally built on seven hills, but it now spans over an area of nineteen hills and it currently has a population exceeding 2 million, which represents approximately 39% of the Jordanian population(department of statistics in Jordan,2014). Factors leading to this situation include: internal rural-urban migration, settlement of nomadic tribes and wars and crises that have affected the region. The burgeoning spatial extent of the city, its rapid growth in all directions, and dramatic population influxes into the city, including during the period of study, were affected by the first Arab Gulf war of 1991 and the invasion of Iraq in 2003(Potter et al, 2007).

Methodology

Methods used to achieve the objectives of this study are illustrated in the methodology flowchart (see Figure2).

The above flowchart divides the study into three main parts: the first is data acquisition in which data was obtained and pre-processed (geometric correction, enhancement, and subsetting).

The second main part was image processing which was divided into two sub-parts: the first is supervised classification based on the maximum likelihood algorithm, in which each dataset were classified into a thematic map and then mathematical calculations is made to do *from-to* change analysis to extract land cover changes. Training sites was selected visually based on the author's knowledge of the city with additional interpretation of Google Earth imagery.

An accuracy assessment was conducted for each data set. The accuracy statistics were used for quantitative analysis the classification accuracy. The accuracies of the classified images were verified with a random sampling method, using a total of 100 sample points. The reference data were examined based on the author's knowledge interpretation for image 1987 and also it was supported by Google Earth of 30/12/2004(*) for image 2003, 8/8/2014 for image 2014 also. Then error matrixes were produced to determine the overall and average accuracies and Kappa coefficient for each image.

The second sub part was clipping the thermal bands from the three images to estimate land surface temperature of each land cover based on NASA calibration models for Landsat TM5 and landsat 8. Landsat TM calibration converts Landsat TM digital numbers to radiance. The formula used in this process for land sat 5 is as follows:

(*) this is the closest date to image 2003 available in Google Earth. The difference between landsat image and Google Earth image is 1 year and 4 months and 20 days. So there is no sufficient change between them.

$$CV_{R1} = \left(\left(LMAX_{\lambda} - LMIN_{\lambda} \right) / \left(QCALMAX - QCALMIN \right) \right) * \left(QCAL - QCALMIN \right) + LMIN_{\lambda} \quad (1)$$

Where:

CV_{R1} is the cell value as radiance

QCAL = digital number

LMINλ = spectral radiance scaled to QCALMIN

LMAXλ = spectral radiance scaled to QCALMAX

QCALMIN = the minimum quantized calibrated pixel value

QCALMAX = the maximum quantized calibrated pixel value and so this equation is used for Landsat 8:

$$L_{\lambda} = M_L Q_{cal} + A_L \quad (2)$$

where:

L_{λ} = TOA spectral radiance (Watts/(m2 * srad * µm))

M_L = Band-specific multiplicative rescaling factor

A_L = Band-specific additive rescaling factor

Q_{cal} = Pixel values (DN)

Table 1: Data Acquisition.

Data Type	Path / Row	Date Acquired	Sun Elevation	Sun Azimuth	Acquisition Quality	Acquisition Time
Landsat TM5	174 / 038	1987/08/14	56.45985509	113.62114745	9	07:37:20 am
Landsat TM5	174 / 038	2003/08/10	59.1206985	114.62603282	9	07:48:11 am
Landsat 8	174 / 038	2014/08/08	63.83587643	120.77937516	9	08:10:52 am
Source: USGS Global Visualization Viewer (http://glovis.usgs.gov/)						

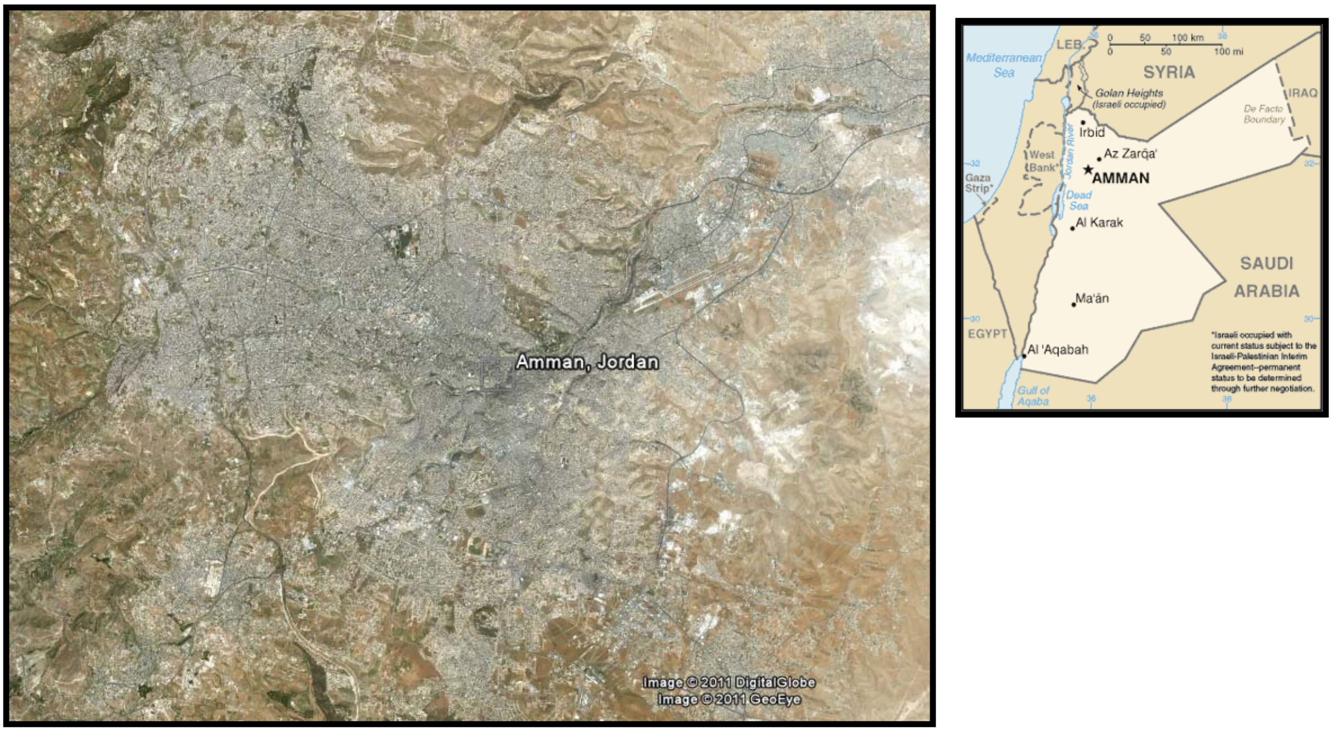

Figure 1: Amman City.

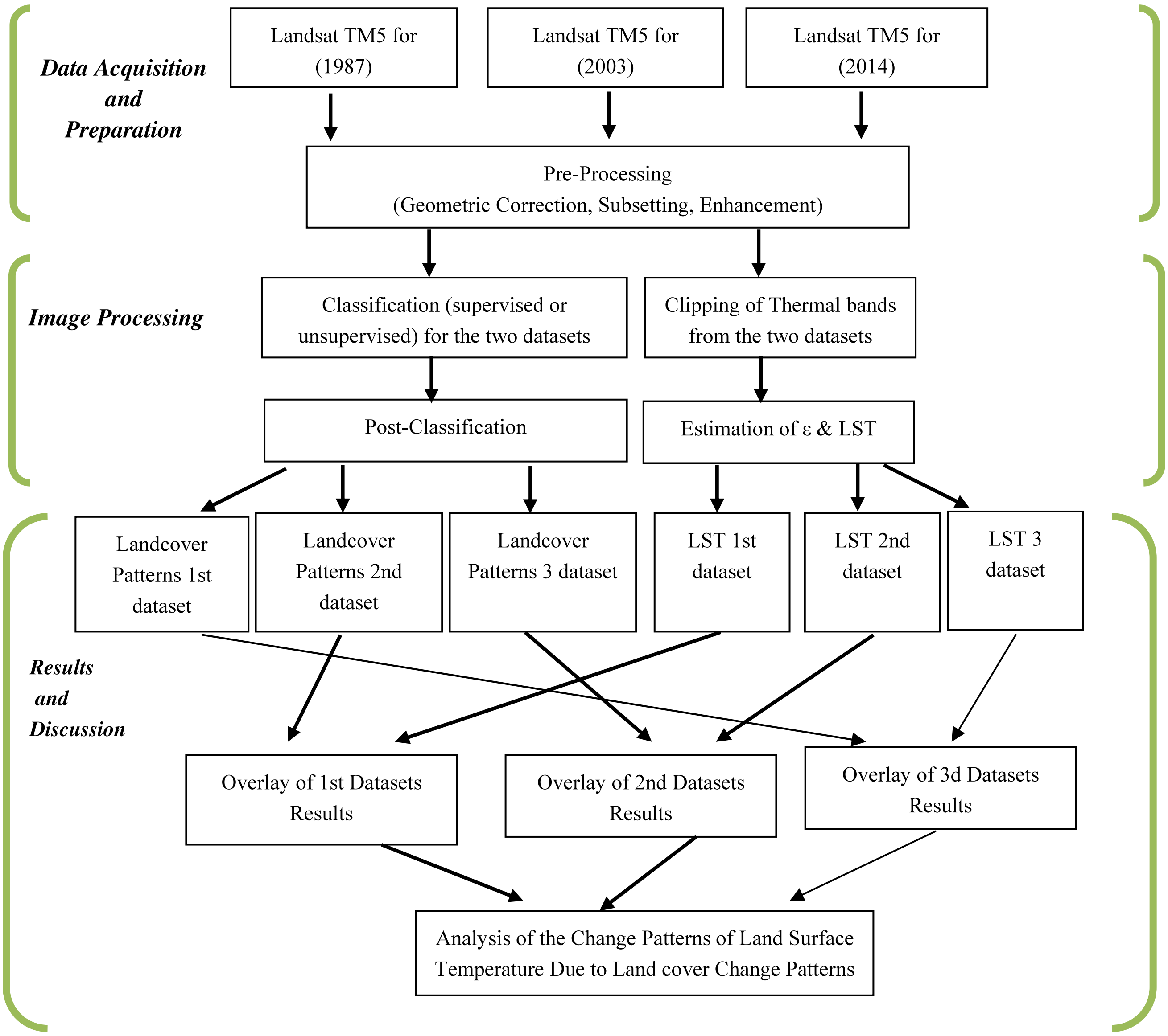

Figure 2: Flowchart shows the Methodology used in the study.

once the DNs for the thermal bands have been converted to radiance values, the next formula is used to convert radiance to kinetic temperature (in Kelvin)[(*)].

$$T = \frac{K_2}{\ln\left(\frac{K_1 * \varepsilon}{CV_{R1}} + 1\right)} \qquad (3)$$

Where:

T = degrees Kelvin

CVR1 = cell value as radiance

ε = emissivity

K1 = 607.76

K2 = 1260.56

K1 = Band-specific thermal conversion constant

K2 = Band-specific thermal conversion constant

To estimate the emissivity, the proportion of vegetation cover per pixel was taking in conjunction with NDVI. The proportion of vegetation cover obtained according to (Carlson & Ripley, 1997).

(*) This formula is used without atmospheric correction.

$$P_v = \left[\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right]^2$$

Where: NDVImax = 0.5 and NDVImin = 0.2 (4)

And the expression for emissivity is given by (Sobrino et al., 2004)

$$\varepsilon\, TM6 = 0.0004\, Pv + 0.986 \quad (5)$$

NDVI was calculated based on the following equation in PCI Modeler (see Figure 3)

$$NDVI = \left[\frac{NIR - Red}{NIR + RED}\right] \quad (6)$$

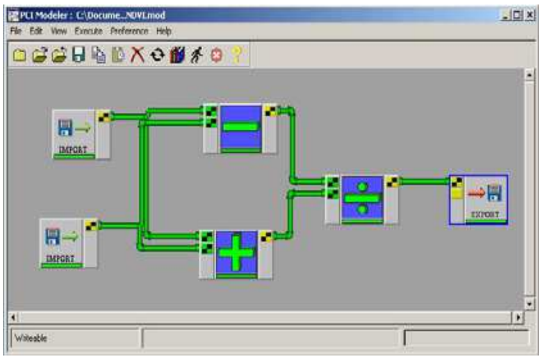

Figure 3: The NDVI Model.

The third main part involves overlaying of part two results using GIS to achieve the main objective of this study. An analysis of temperature changes associated with various land cover changes will be conducted.

Results and Discussion

Image Classification

For image classification, supervised classification was performed based on the maximum likelihood algorithm; four classes of land cover were classified. The classes are Built-up area, Vacant Land, Vegetation and Quarries & Restructured Areas. The overall accuracies were 97.73 % and 97.02% an 90% for the 1987 and 2003 and 2014 images respectively. Table 2 and Figure 4 show the results of the supervised classification of image 1987 and Image 2003 and 2014.

Table 2: The Result of Supervised Classification and the Area of Each Class for Images 1987, 2003 and 2014

Class #	Type Name	percentage%		
		1987	2003	2014
1	Built-up Area	19.77	40.4	43.7
2	Vacant Land	54.7	47.0	45.8
3	Vegetation	13.6	7.3	6.9
4	Quarries & Restructured Areas	11.9	5.3	3.6
	Total	100.00	100.00	100.00

It is clear from the results of the study that the area of the built up area has increased during the period from 1987 to 2003. Table 2 shows that the vacant land covers the largest area with 54.73% and 47.00% and 45.8% in the 1987 and 2003 and 2014 images respectively. Thus, the percentage of the vacant lands has decreased by 7.73% during the period 1987 to 2003 and decreased 8.9% during the period 1987 to 2014 and 1.8% during the period 2003-2014. The built-up area has expanded and doubled during the study period where its percentage increased from 19.76% in 1987 to 40.40% in 2003 and 43.7% in 2014 based on the analysis made for the images of each year. The area of vegetation has also decreased by 6.34% going down from 13.60% in 1987 to only share 7.3% in 2003 and also decreased to 6.9% in 2014 of the total area covered in this study, and finally, the area of the quarries & restructured areas has also decreased from 11.9% to 5.33% to 3.6% for images 1987 and 2003 and 2014 respectively.

Accuracy Assessment

For accuracy assessment, 100 random points were used for the four classes. The statistics shows that the overall accuracies are 92% and 99% and 90% and the overall Kappa statistics are 0.872 % and 0.783% and 84.5 for image 1987 and image 2003 and image 2014 respectively. Kappa statistics represented a strong agreement or accuracy between the classification map and the reference information for image 1987 and moderate agreement in image 2003 and image 2014[1(*)]. Table 3 shows the accuracy assessment statistics.

(*) Kappa values >80% represent strong agreement, 40%-80% represents moderate agreement and <40% represents poor agreement. Jensen, J. Introductory Digital Image Processing - a Remote Sensing Prospective-, Person Education, 2005, 508.

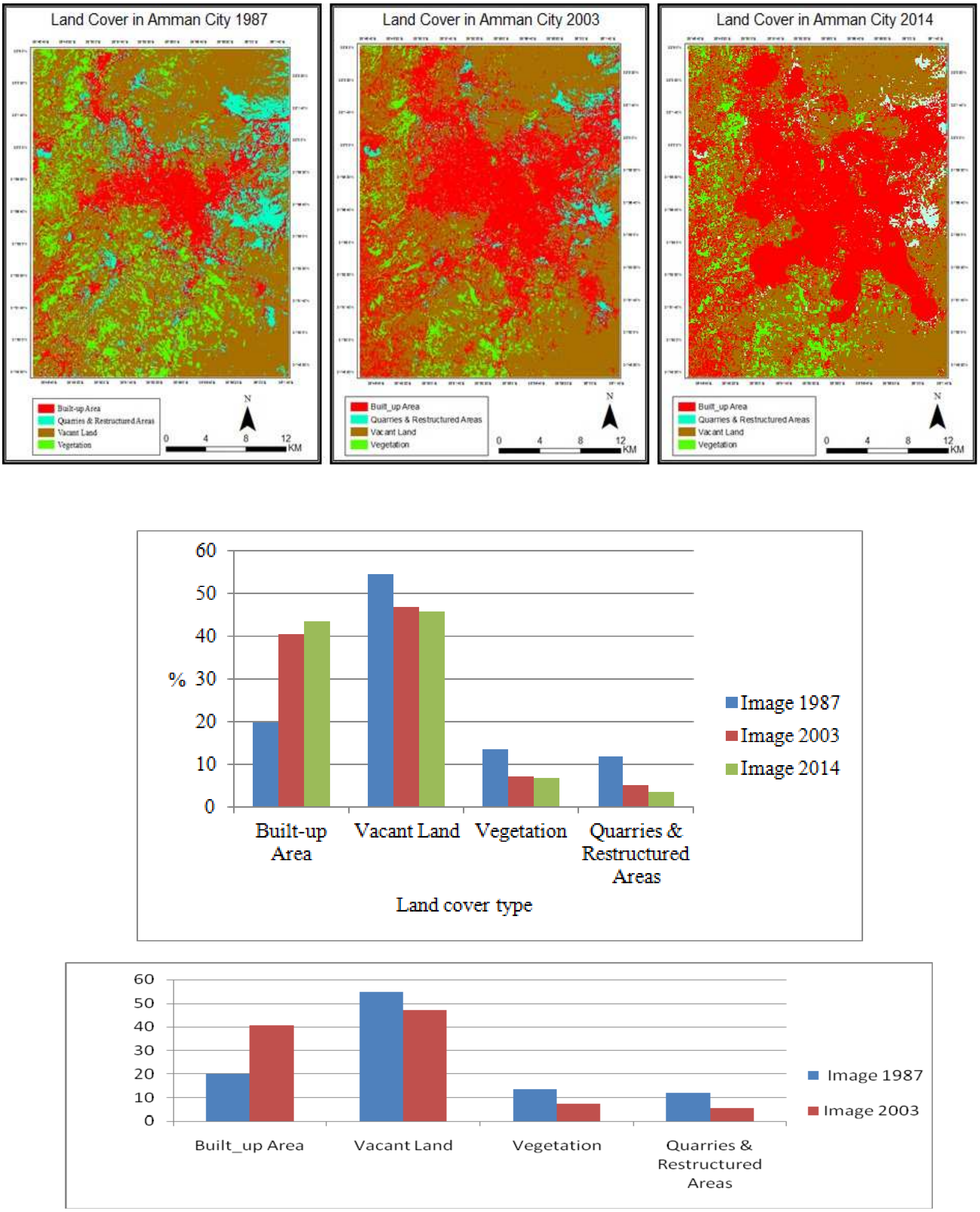

Figure 4: Land Cover changes within the study area based on the results of LANDSAT TM5 images taken on, 14th of August 1987 and 10th of August 2003 and 2014.

Table3: Accuracy Assessment Statistics for Images 1987, 2003, 2014

Class name	Producer's Accuracy %			User's Accuracy %			Kappa Statistic		
	1987	**2003**	**2014**	**1987**	**2003**	**2014**	**1987**	**2003**	**2014**
Built-up Area	84.21	86.84	85.23	94.12	84.62	87.9	0.93	0.76	0.81
Vacant Land	98.148	88.37	93.30	92.98	86.36	90.43	0.85	0.76	0.78
Vegetation	87.5	88.89	85.92	93.333	80.00	85.36	0.92	0.78	0.90
Quarries & Restructured Areas	81.82	70.00	78.83	81.82	100.00	93.13	0.80	1.00	0.89

Image 1987: Overall Accuracy: 92 % Overall Kappa Statistic: 0.872%
Image 2003: Overall Accuracy: 86 % Overall Kappa Statistic: 0.783%
Image 2014: Overall Accuracy: 88 % Overall Kappa Statistic: 0.823%

Analysis of Land Surface Temperature and Relationship with Land Cover

Analysis of the overall Land Surface Temperature

The spatial distribution of land surface temperature of LANDSAT TM5, 14th of August 1987 and LANDSAT TM5, 10th of August 2003 and landsat8 , (8th of august 2014) are shown in figure 5. Figure 5 also shows that the center parts of the city exhibit higher temperature in each images due to the built up area while it become lower as we go far from the centre part. The overall land surface temperature ranged from 19°C to 29°C with a mean of 23.9°C and standard deviation of 3.0°C for the 1987 image and it ranged from 20°C to 32°C with a mean of 26.2°C and standard deviation of 4.1°C for the 2003 image and ranged from 20°C to 27.1°C for 2014 as shown in Table 4. The table shows that the overall mean temperature was increased by 3.1°C which can be considered as a strong indicator of the effect of the increase of the built up area between 1987 and 2014 on the LST.

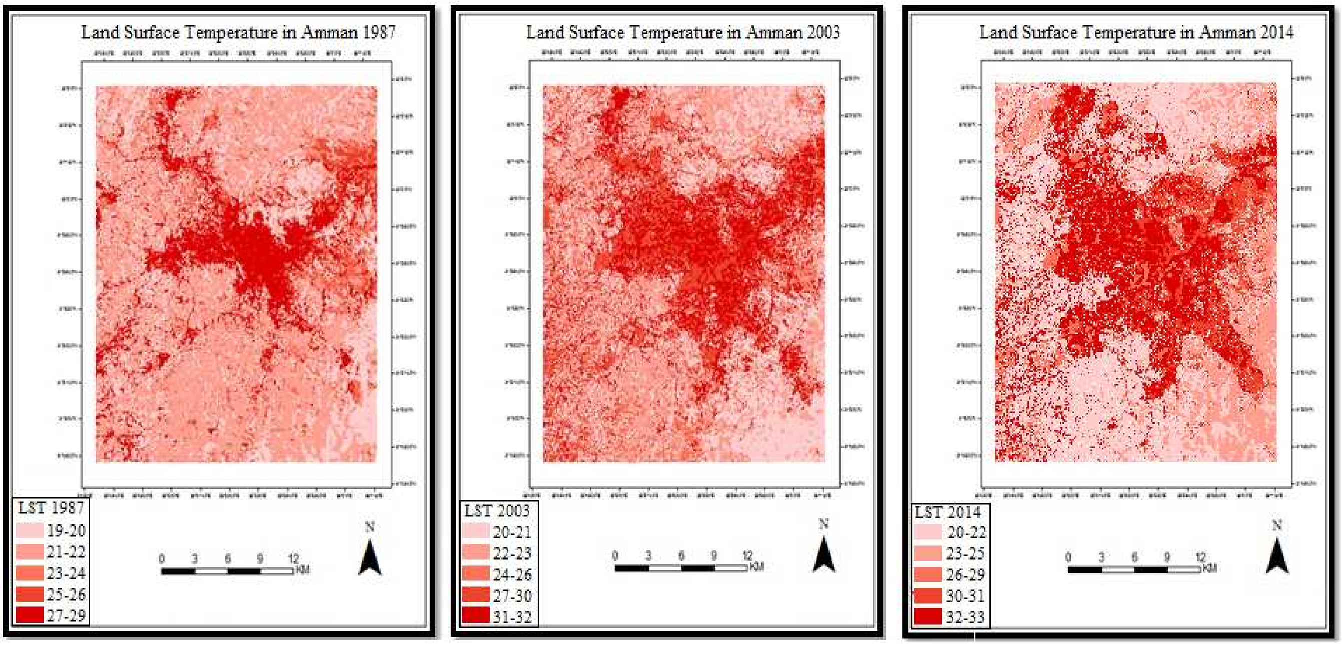

Figure 5: Spatial Distribution of Land Surface Temperature of LANDSAT TM5, 14th of August 1987 and LANDSAT TM5, 10th of August 2003. and 2014

Table 4: The overall Land Surface Temperature of LANDSAT TM5, 14th of August 1987 and LANDSAT TM5, 10th of August 2003, landsat8 8th of august 2014

Overall LST 1987				Overall LST 2003				Overall LST 2014			
Min	**Max**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**
19	29	23.9	3	20	32	26.2	4.1	20	33	27.1	4.5

Analysis of the Land Surface Temperature for each land cover types

Table 5 shows the estimated land surface temperature of each land cover type for each images. The table shows that LST values were increased for each land cove type for the2014 image compared to the 1987 image, except for the Vegetation. The mean for temperature values of the built up area was increased by 4°C from 26.9°C in 1987 to 30.9 in 2014. The mean of temperature values for Vacant Land was also increased by 1.7°C,from 19.8°C in 1987 to 21.5°C in 2014. The mean of temperature values for Quarries & Restructured Areas was increased by 0.1°C, from 23.5°C to 23.6°C for the same period. Finally, the mean of temperature values for Vegetation was decreased by -2.6°C from 24.2°C to 21.9°C for the same period (see Figures 6 and 7). These results show a strong evidence and relationship on the effects of the changes of land cover types on the local temperature of the city. It shows a positive correlation between the area of built up area and the LST.

Table 5: Estimated LST (°C) of LANDSAT TM5, 14th of August 1987 and LANDSAT TM5, 10th of August 2003for Each Land Cover Class. Av. = Average, SD = Standard Deviation

Land Cover Type	Detailed LST 1987 / °C				Detailed LST 2003 / °C				Detailed LST 2014 / °C			
	Min	**Max**	**Av.**	**SD.**	**Min**	**Max**	**Av.**	**SD**	**Min**	**Max**	**Av.**	**SD**
Built-up Area	25	29	26.9	1.3	28	32	30.4	1.4	28	33	30.9	1.6
Vacant Land	19	21	19.8	0.8	20	23	21.9	1.05	21	23	21.5	0.7
Vegetation	23	26	24.2	0.7	21	23	21.9	0.7	20	23	21.6	0.8
Quarries & Restructured Areas	22	25	23.5	1.2	23	26	24.4	0.8	23	25	23.6	0.8

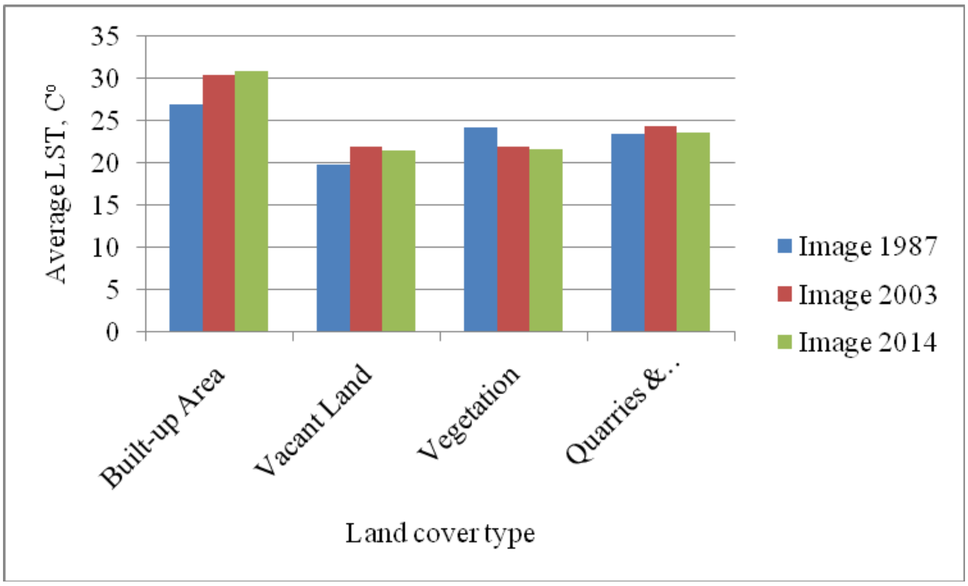

Figure 6: LST Average Values for Each Land Cover Type for each year.

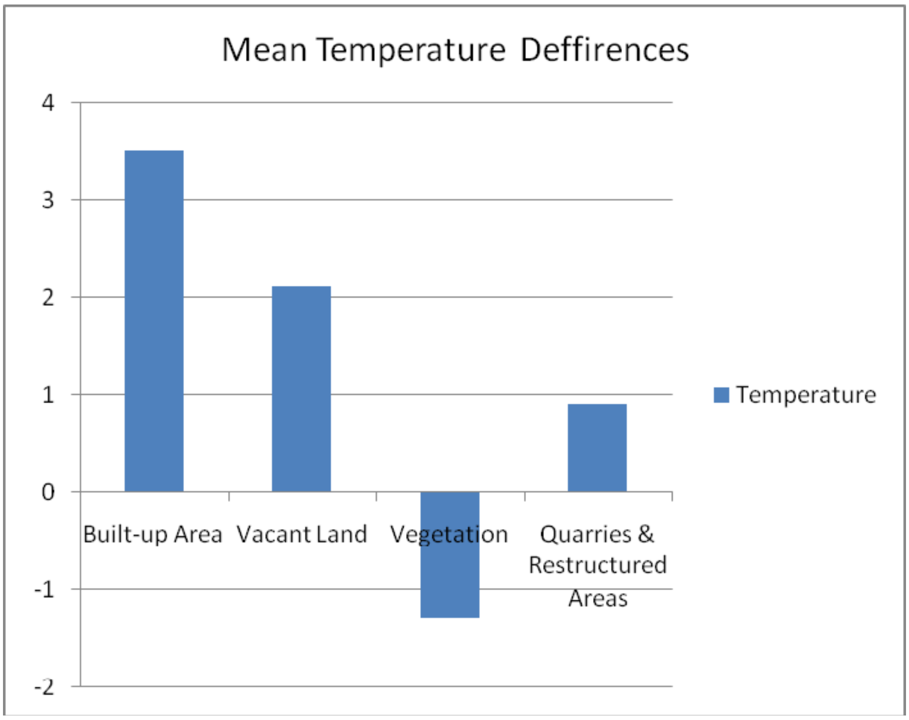

Figure 7: The Differences in LST Mean Values for Each Land Cover Type.

Conclusion

Remote sensing techniques provide data and tools used for detecting changes of land cover patterns, and estimating land surface temperature. This study aimed to examine these capabilities by taking Amman city (the capital of Jordan) as the area of this study. Landsat TM5 datasets for the years 1987 and 2003 and 2014 were used for the analysis. The analysis included four parts which are: supervised classification, calculating the changes in areas, land surface temperature estimation and overlapping the results. Four classes were classified within the study area: Built-up area, Vacant Land, Vegetation and Quarries & Restructured Areas. The overall differences in LST mean values for each land cover type showed increasing in image 2014 by about 3.2°C where built-up area increased by 4°C, vacant land by1.7 and vegetation decreased by 2.6°C and quarries & restructured areas decreased by 0.1°C.

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آثار التغيرات في الغطاء الأرضي على درجة حرارة سطح الأرض في مدينة عمان: دراسة تغير المناخ الحضري

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ملخص

هدفت هذه الدراسة الى دراسة آثار التغير في أنماط الغطاء الأرضي على درجة حرارة سطح الأرض في مدينة عمان. وقد تم استخدام تقنيات الاستشعار عن بعد في هذا البحث لدراسة العلاقة بين التغير في الغطاء الأرضي ودرجة حرارة سطح الأرض في مدينة عمان، واستخدمت مجموعات بيانات لاندسات TM5 للسنوات 1987 و2003، في التحليل باستخدام PCI Geomatica 9.1لغايات التصنيف والتحليل الموجه، والاستفادة من برنامج ENVI4.5 لتقدير درجة الحرارة سطح الأرض، وبرمجية ArcGIS9.3 لاجراء المضاهاة الطبقيه لنتائج الدراسة من خلال مطابقة أكثر من طبقة من البيانات.

تم تصنيف أربع فئات من الغطاء الأرضي في منطقة الدراسة هي: المساحات المبنية، والأراضي الشاغرة (الخالية)، والأراضي الخضراء والمحاجر والمناطق تحت التأهيل. تم فحص دقة البيانات لكل مجموعة حيث أظهرت الإحصاءات أن الدقة الإجمالية هي 92٪ و86٪ و88% وإحصاءات كابا الشاملة 0.872٪ و0.783٪ و0.823 للسنوات 1987 و2003 و2014 على التوالي. تراوحت درجة حرارة سطح الأرض الإجمالية من 19 C ° إلى 29 C ° بمتوسط 23.9 درجة مئوية، وانحراف معياري 3.0 درجة مئوية في عام 1987، تراوحت درجات الحرارة من 20 C ° إلى 32 C ° بمتوسط 26.2 درجة مئوية، وانحراف معياري 4.1 C ° لعام 2003، بزيادة المتوسط العام لدرجة الحرارة بمقدار 2.3 درجة مئوية. وأظهرت النتائج ارتفاع درجة حرارة السطح للأنماط الأرضية الثلاثة (الأراضي المبنية، الأراضي الفراغ، والمناطق تحت التأهيل) في الفترة بين 1987 إلى 2014. أما الأراضي الخضراء فلم تشهد ارتفاعاً في درجة حرارة السطح. فقد ارتفع متوسط قيمة درجة الحرارة في المنطقة المبنية بمقدار 3.5 درجة مئوية، وبمقدار 2.1 درجة مئوية للأراضي الغراغ (الخالية) وبزيادة مقدارها 0.9 درجة لمناطق المحاجر والمناطق المعاد، في حين انخفض متوسط قيم درجة حرارة الغطاء النباتي بمقدار 1.3 درجة مئوية. وتبين هذه النتائج وجود أدلة قوية على علاقة وآثار التغييرات في انماط الغطاء الأرضي على درجة الحرارة المحلية للمدينة.

الكلمات الدالـة: التغيير، الغطاء الأرضي، حرارة، عمان.

* قسم الجغرافيا، كلية الآداب، جامعة اليرموك، اربد، الأردن. تاريخ استلام البحث 2014/8/12، وتاريخ قبوله 2014/11/26.