MAPPING LAND COVER CHANGES OF PILGRIMAGE SITES IN MECCA USING MULTI-TEMPORAL SATELLITE IMAGERY

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Abstract

The Pilgrimage sites (Mina, Arafat and Muzdalifah) located in the southeast part of the holy city of Mecca, Saudi Arabia, or “Hajj Sites” as it is known, are one of the most important annual assembly areas for Muslims from all over the world and being visited by millions of pilgrims every year to perform the Islamic pilgrimage (Hajj). The sites have undergone significant change in land cover since the government embarked on a course of intense development projects 20 years ago, as a result of the increase in the number of pilgrims every year. Considering lack of studies that measure and evaluate land cover changes of the sites, this study detects, analyzes and evaluates land cover changes in Hajj sites from 1997 to 2013 using Landsat images of four different time periods, i.e., Landsat Thematic Mapper (TM) of 1998, and Lamdsat Enhanced Thematic Mapper Plus(ETM+) of 2003, 2008 and 2013. The supervised classification methodology has been employed through testing its different techniques to obtain the best possible result; the images of the study area were categorized into five different classes’ namely Built-up areas, Street, Mountain, un built-up and Vegetation. The comparison (pixel by pixel) was used to land cover changes detection. Generally, the results show a noticeable increase in area on both built-up and street due to the rapid development in the areas with decrease in vegetation and un built-up. The provided information, combined with the field observation work is essential for assist future planning and decisions in one hand, and on

the other hand can play an important role in quantifying and understanding the relationship between population growth (pilgrims) and land cover changes.

Introduction

Each year, over 3 million Muslims perform the *Hajj* (Islamic pilgrimage) to Mecca and surrounds including Hajj sites called (Mina, Arafat and Muzdalifa). It is the world's largest gathering of Muslims and the biggest annual gathering in the world (CNN, 2011). Thus, it presents specific logistical challenges for the government of Saudi Arabia. According to the Saudi Press Agency, as recently as 1950 the number of pilgrims during Hajj was less than 100,000. That number doubled by 1955, and in 1972 had reached 645,000. In 1983, the number of pilgrims coming from abroad exceeded one million for the first time (Chalmers, 2011). In recent years, Saudi Arabia has hosted over 1.5 million pilgrims from abroad as well as another million from within the Kingdom. This vast number of pilgrims in a limited geographic areas and specific time has created myriad challenges for the Saudi government. The sites have undergone significant change in land cover since the government embarked on a course of intense development projects 20 years ago, as a result of the increase in the number of pilgrims every year. Considering that the measurement and monitoring of land cover changes in any area are crucial to government officials and planners who need updated information for planning and management purposes (Yeh et al., 2001). The main objective of this paper is to detect, identify, and measure the composition of land cover changes of Hajj sites using multi-temporal satellite imagery. Such information is fundamental for a better understanding the relationships and interactions between humans and the natural environment (Dewan et al., 2009). Furthermore, change detection means the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). However, a variety of digital change detection techniques has been developed in the past three decades (Nori et al., 2008), remote Sensing data and techniques, in combination with GIS and landscape metrics, are fundamental to analyze and characterize Land Cover and its changes (Fichera et al., 2012). In fact, multi-temporal RS datasets, opportunely processed and elaborated, allow mapping and identifying landscape changes, giving an effective effort to sustainable landscape planning and management (Dewan et al., 2009). The availability of time-series dataset is essential to understand and monitor the urban expansion process, in order to characterise and locate the evolution trends at a detailed level. In fact, during the last three decades, satellite time series as Landsat images have been exploited in several studies (Masek et al., 2000; Yang and Lo, 2002; Yuan et al., 2005). By means of the integration of remote sensing and GIS techniques, it is possible to analyze and to classify the changing pattern of land cover during a long time period and, as a result, to understand the changes within the area of interest (Fichera et al., 2012).

Islamic Pilgrimage

The performance of the Hajj (Islamic Pilgrimage) to Mecca is the fifth pillar of Islam after the profession of monotheistic faith, acceptance of the daily ritual of five prayers, giving of alms and fasting of Ramadan. Able Muslims who fulfill certain conditions are obligated to perform Hajj once during their lives. It falls during the Islamic lunar month of Dhu'l-hijjah[1] each year , It is a set of acts of worship involves several rituals and praying designed to be performed in Mecca and its surrounding sacred sites located about 5 miles from Mecca and known as (Mina, Arafat and Muzdalifah), with the goal to bring the faithful closer to God

In Islam, pilgrimage is an essential practice. For Muslims, the origins of the Hajj and the holy places of Mecca lie deep in the primeval past. According to the Qur'an, Abraham and his son Ishmael laid the foundations of the Ka'ba in Mecca, offering the structure to Allah: "when Abraham was raising the plinth of the House with Ishmael, (he prayed): 'Accept this from us, O Lord'" (Qur'an, 2:127).[2] Later Islamic tradition claimed that Adam had already hallowed the site.[3] But the cult dedicated to the worship of Allah degenerated, and the Meccans "exchanged the religion of Abraham and Ishmael for another."[4]

As the host city of the Ka'ba, Mecca had been a pagan pilgrimage site since antiquity, and was likely in use as such for millennia before Muhammad. There is little doubt that pre-Islamic Arabs had a cult of stones at the site of the Ka'ba.[5] The Qur'an takes note of this, even mentioning that the months for pilgrimage were matters of common knowledge (Qur'an, 2:197).

The pre-Islamic pilgrimage was composed of a series of rituals. Muhammad took those traditions and reoriented them away from the worship of idols toward the worship of Allah. In effect, "the later Muslim tradition 'harmonized' the Islamic version of the complex by identifying each of its elements with some incident in the Abraham legend, which was itself enriched by association with otherwise inexplicable practices in the Hajj ritual."[6]

Study area

The Hajj sites are located in the southeastern part of the Mecca. It covers area between 21°N latitude and 39°E longitudes with an area of approximately 113km². The sites are covered by hill and desert terrain around them, and have an average temperature of 40˚C in summer and 30˚C in winter. the past 20 years, Mecca and Hajj sites have experienced rapid urbanization and exhibit a wide variety of land use and land cover types, as they are the most revered holy places of the international Muslim community, receive more than 3 million visitors annually, embracing the rituals of the Hajj pilgrimage (Alqurashi and Lalit, 2014). The sites include three places called Mina, Muzdalifa and Arafat, the nearest to Mecca is the narrow valley of Mina, which lies about 7 km north-east of the Great Mosque and it is surrounded by high and steep rocks and its eastern canonical border is a dry riverbed. 6 km further to the east one finds the plane of Muzdalifa, a wide valley with a little hill, which is enclosed by some rocky mountains, forming a narrow pass. Through this the path of the pilgrims leads a further 7 km to the east to

[1] The Islamic calendar, Muslim calendar or Hijri calendar (AH) is a lunar calendar consisting of 12 months in a year of 354 or 355 days. It is used to date events in many Muslim countries (concurrently with the Gregorian calendar), and used by Muslims everywhere to determine the proper days on which to observe the annual fast (see Ramadan), to attend Hajj, and to celebrate other Islamic holidays and festivals.

[2] Quotations from the Qur'an are from Ahmed Ali, Al-Qur'an: A Contemporary Translation, rev. ed., 9th paperback printing (Princeton, N.J.: Princeton University Press, 1993).

[3] F. E. Peters, The Hajj: The Muslim Pilgrimage to Mecca and the Holy Places (Princeton, N.J.: Princeton University Press, 1994), 7.

[4] Ibn al-Kalbi, quoted in Peters, Hajj, 21.

[5] Peters, Hajj, 21.

[6] Ibid., 31.

the valley of Arafat enclosed in the West by a dry riverbed and in the east by a comparatively low mountain range (Figure 1).

Figure 1. Mecca and hajj sites map

Source: http://www.mapsofworld.com/saudi-arabia/maps/makkah-map.jpg

Material and methods

Database preparation

Landsat Thematic Mapper at a resolution of 30 m of 1998, 2003, 2008 and 2013 were used for land cover classification. The satellite data covering study area were obtained from the USGS Earth Explorer site (table 1). All four images were geometrically corrected and rectified to UTM zone 37. These data sets were imported in ENVI software version 5.1. The sub-setting of satellite images were performed for extracting study area from both images by taking geo-referenced out line boundary of sacred sites district in Mecca as (Area of Interest), which was obtained from the official Mecca municipality webpage. The filling Gaps process was applied to both images of 2003 and 2008 using a technique developed by Scaramuzza, et al (2004) in order to correct the failure of the sensor of Landsat 7 Enhanced Thematic Mapper (ETM) occurred on May 2003 (Chen et al., 2011). Furthermore, Images resolution of Landsat 7 Thematic Mapper Plus (ETM+) has been enhanced through the pan-sharpening method through the merge of multispectral bands with the 15-meter panchromatic band, without losing the RGB information from the original multispectral three-band 30-meter composite. The objective of the sharpening was to improve the spatial resolution of the multispectral imagery, while preserving the spectral information in homogeneous areas (King and Jianwen, 2001).

Table 1. Dataset used for this paper

Year	Satellite	Sensor type (Dataset)	Acquisition Date	Spatial Resolution
1998	LANDSAT_5	TM	8/25/1998	30 m
2003	LANDSAT_7	ETM+	8/15/2003	30 m
2008	LANDSAT_7	ETM+	8/28/2008	30 m
2013	LANDSAT_7	ETM+	8/26/2013	30 m

Source: Author preparation

Images classification

To work out the land cover classification, supervised classification method with maximum likelihood algorithm was applied in the ENVI 5.1 Software. It is one of the most popular supervised classification methods used with remote sensing image data (Rawat and Kumar, 2015). This method will classify the image based on the training sets (signatures) provided by the user based on his field knowledge. The training data given by the user guides the software as to what types of pixels are to be selected for certain land cover type (Hegazy and Kaloop, 2015). The classification finally gives the land cover image of the area. Five land cover classes namely *vegetation, built up, street, un-built-up and mountain* were identified in the study area (table 2). The classified images provide all the information to understand the land cover of the study area(Figure). However, considering that no land cover assessment is completed without checking their accuracy of the classified images that generated from the classification process (Mustapha et al., 2011), In this study the confusion matrix method through the ground truth data was applied to the classified images in order to calculate and tabulate the overall classification accuracy and Kappa Coefficient.

Table 2. Description of these land cover classes

Land Cover Classes	Description
Built-up	Residential, commercial services, industrial, mixed urban or built-up land
Street	Including all roads network
Un-Built-up	Bare soil, sandy soil, desert, open land
Vegetation	Trees, agriculture area, vegetated area
Mountain	Hill, large rock, rugged terrain

Source: Author preparation

Change detection analysis

Change detection analyses describe and quantify differences between images of the same scene at different times (Hegazy and Kaloop, 2015). The classified images of the four dates can be used to calculate the area of different land covers and observe the changes that are taking place in the span of data. This analysis is very much helpful to identify various changes occurring in different classes of land use like increase in built-up area or decrease in vegetation area and so on. There are many methods of change detection available (Lu et al., 2004). In the case-study here described, the methodology followed has been the “Post-classification comparison”, This method detects changes in land cover type comparing pixel by pixel the classified images. Jointly with “Post-classification comparison”, a GIS has been combined, to efficiently integrate land cover maps and to quantitatively reveal the change dynamics in each category. The advantage of GIS techniques it’s not only linked to exploitation of database capabilities, but also to the ability to manage different land cover maps by means of typical operators like “intersect” and “union”, in order to easily evaluate the amount of change [Petit and Lambin, 2001].

Results and discussion

Land cover changes

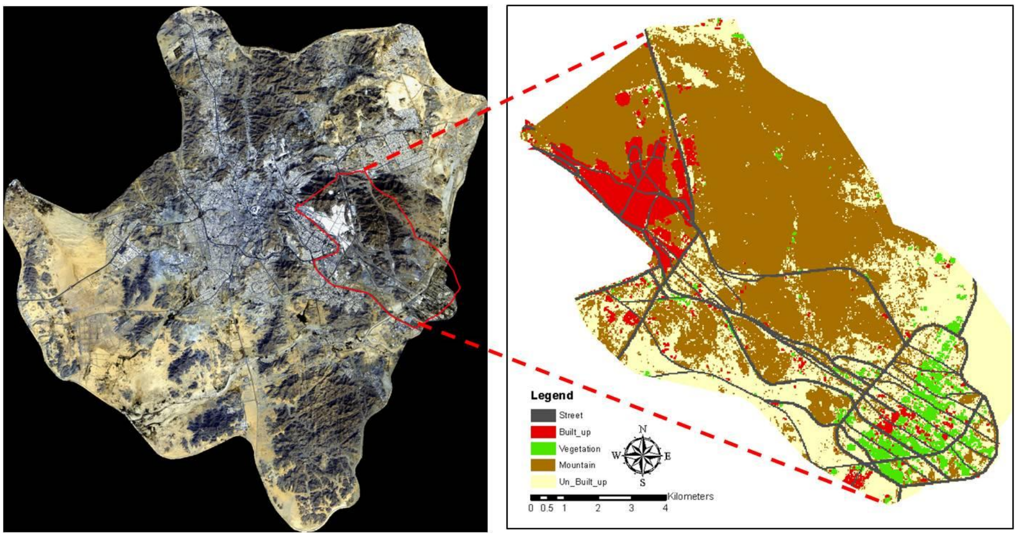
The results coming from the study here described were diagrammatically illustrated in (Figure 2 and 3). The statistics and the percentages of land cover change are registered in (Tables 3). It is clear from the table that there was a considerable change in land cover in sacred sites during the 20-year study period. Built-up area increased by approximately 5.6 km² (147.54%). There were also a little increased in both vegetation and street cover by approximately 0.14 km² (3.39%) and 0.46 km² (7.17%) respectively. Mountatin is the dominant land cover class in the area because of its geographical location on the Al-Sarawat Mountain range (Alqurashi et al., 2014), the un-Built-up class forms another major class of land cover. Un-Built-up cover showed a decrease of -8.55 km² (-27.3%) as a result of the increase in the others classes. Mountain cover strangely showed an increase of 2.35 km² (3.48%) especially between 2008 and 2013, which could be because of the demolish work to provide more space for pilgrims. It is noticed that most of change occurred in Built-up area was between 1998 and 2003 at range of (80.81%) and that because Mina had the project of the improved permanent tents project started in respond to the fire broke in 1997 and finished in 2001. On the other hand there was fluctuate in vegetation cover area as showed the table that there was a decrease (-6.45%) between 1998 and 2003 and an increase of (22.78%) between 2003 and 2008 and a little increase of (3.72%) between 2008 and 2013.

Table 3. Results of land cover classification showing area change and percentage change

land cover	1998		2003		Change between 1998-2003 by %	2008		Change between 2003-2008 by %	2013		Change between 2008-2013 by %	1998 - 2013 Total change	
	Area		Area			Area			Area				
	Km²	%	Km²	%		Km²	%		Km²	%		Km²	%
Built_up	3.80	3.36	6.87	6.07	80.81	8.16	7.22	18.85	9.40	8.31	15.19	5.60	147.54
vegetation	4.07	3.59	3.80	3.36	-6.45	4.67	4.13	22.78	4.20	3.72	-9.99	0.14	3.39
street	6.39	5.65	6.49	5.74	1.46	7.01	6.20	8.09	6.85	6.06	-2.28	0.46	7.17
mountain	67.54	59.71	64.96	57.43	-3.82	64.06	56.63	-1.39	69.89	61.79	9.10	2.35	3.48
un_built_up	31.32	27.69	31.00	27.40	-1.02	29.21	25.83	-5.75	22.77	20.13	-22.07	-8.55	-27.30

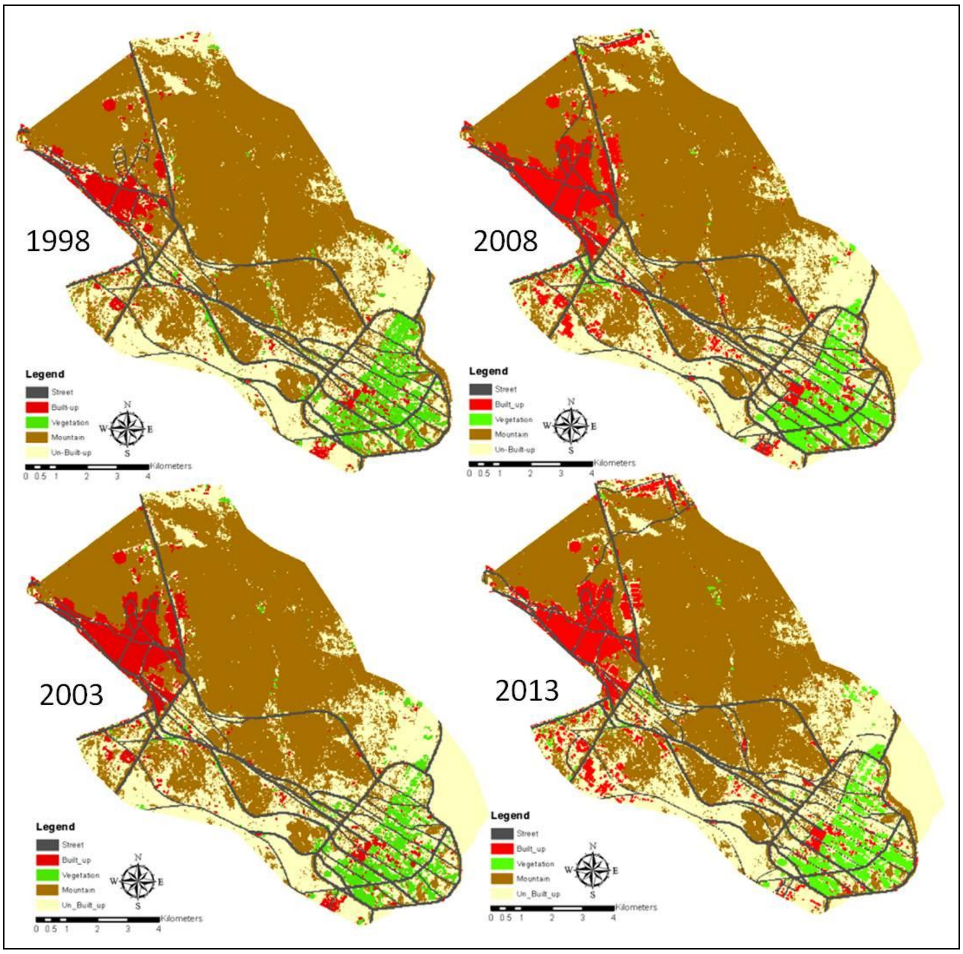
Source: Author preparation

Figure 2. Classification from the satellite image



Source: Author preparation

Figure 3. **maps of the major land cover types and the changes from 1998 to 2013**



Source: Author preparation

Accuracy assessment

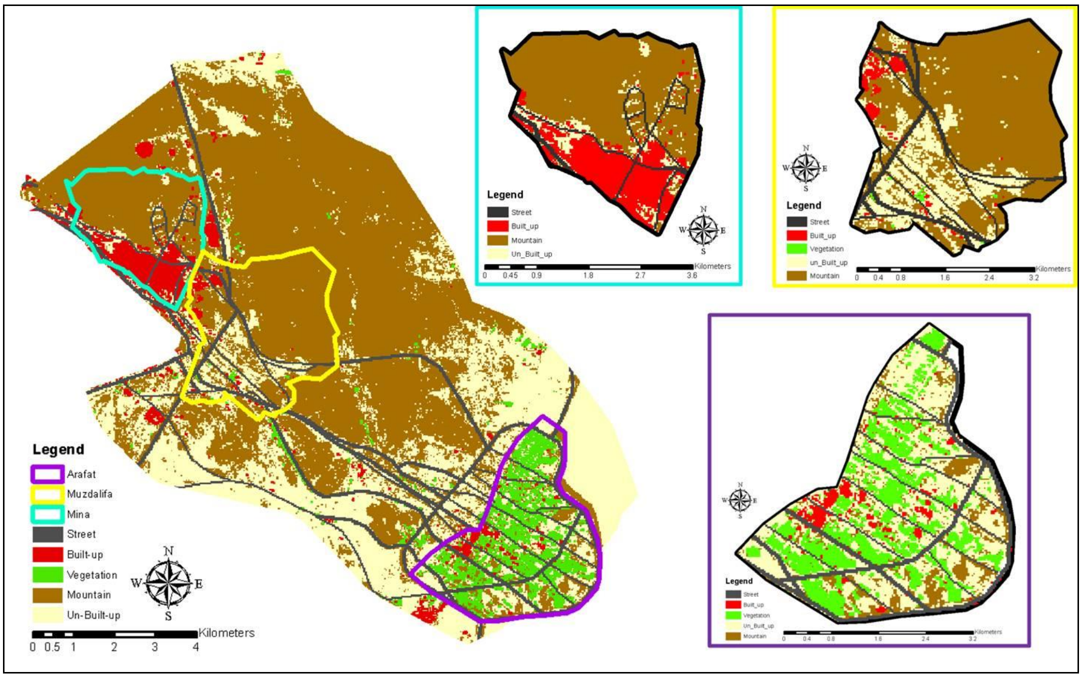
Accuracy assessment of the land cover classification results obtained showed an overall accuracy of 84.64%, 84.8%, 83.56% and 83.72% for 1998, 2003, 2008 and 2013 respectively (Table 4). 500 samples were selected randomly in order to examine the image classification accuracies. The producer's and user's accuracies showed the highest percentage in the urban class, however, the accuracies of vegetation class also showed a high percentage because the vegetation gives a unique spectral reflectance in the near-infrared bands. The low percentage of producer's accuracies was found in street class because of the mixed pixels with other classes. Finally, the producer's accuracies of mountain and soil class showed high percentage while the user's accuracies showed low percentage value.

Table 4. Summary of classification accuracies

Land Cover Category	1998		2003		2008		2013	
	Accuracy		Accuracy		Accuracy		Accuracy	
	Producer's	User's	Producer's	User's	Producer's	User's	Producer's	User's
Urban	90.2	87.91	95.6	89.01	98.6	89.15	97	96.81
Vegetation	70	99.72	75	100	67.2	100	83.2	99.76
Street	67	91.28	54.4	96.11	52.4	100	45.4	78.82
Soil	100	75.64	100	68.21	100	66.49	100	62.34
Mountain	96	78.95	99	86.54	99.6	83.42	93	94.51
Overall Accuracy	84.64		84.80%		83.56%		83.72%	
Kappa Coefficient	0.808		0.810		0.7945		0.7965	

Source: Author preparation

Figure 4. Maps of the three Hajj places inside sacred district



Source: Author preparation

The three hajj places

As mentioned before that the sacred district includes three places called Mina, Arafat and Muzdalifa. Each one has its land cover character depending on the ritual assigned there (figure 3). In this study we have also mapped the land cover changes for each place separately in order to understand better land cover changes of the whole sacred sites district. Therefore, results show that most changes in Mina, Muzdalifa and Arafat was an increase in the built-up cover by approximately 1.83 km² (104.01%), 0.82 km² (273.88%) and 0.38 km² (107.68%) respectively. The highest change was between 1998 and 2003 as a result of the tent project mentioned before. Moreover, vegetation cover has increased in Muzdalifa by approximately 0.02 km² (65.97%), where in Arafat the vegetation cover had fluctuate during the period of study (Table 5,6 and 7).

Table 5. Mina land cover changes by km² and by percentage

Mina										
Land cover categories	1998		2003		2008		2013		Change 98-13	
	km2	%	km2	%	km2	%	km2	%	km2	%
Built_up	1.76	22.54	3.36	43.01	3.53	45.27	3.59	45.98	1.83	104.01
un_built_up	0.75	9.64	0.17	2.13	0.13	1.61	0.12	1.52	-0.63	-84.24
vegetation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
street	0.41	5.26	0.41	5.26	0.43	5.49	0.46	5.84	0.04	10.93
mountain	4.88	62.56	3.87	49.59	3.71	47.54	3.64	46.62	-1.24	-25.47

Source: Author preparation

Table 6. Muzdalifa land cover changes by km² and by percentage

Muzdalifa										
Land cover categories	1998		2003		2008		2013		Change 98-13	
	km2	%	km2	%	km2	%	km2	%	km2	%
Built_up	0.30	2.56	0.76	6.51	0.81	6.94	1.12	9.59	0.82	273.88
un_built_up	2.22	18.99	2.04	17.44	2.00	17.14	1.72	14.72	-0.50	-22.49
vegetation	0.04	0.32	0.06	0.54	0.10	0.87	0.06	0.54	0.02	65.97
street	0.89	7.64	0.89	7.64	0.90	7.66	0.93	7.99	0.04	4.53
mountain	8.23	70.48	7.93	67.87	7.87	67.40	7.85	67.16	-0.39	-4.71

Source: Author preparation

Table 7. Arafat land cover changes by km² and by percentage

Arafat										
Land cover categories	1998		2003		2008		2013		Change 98-13	
	km2	%	km2	%	km2	%	km2	%	km2	%
Built_up	0.35	3.29	0.43	4.14	0.57	5.47	0.72	6.84	0.37	107.68
un_built_up	2.87	27.39	3.69	35.22	2.89	27.53	2.64	25.15	-0.23	-8.16
vegetation	2.76	26.31	2.26	21.58	3.22	30.73	2.62	25.03	-0.13	0.00
street	1.02	9.72	1.05	10.06	1.07	10.25	1.90	18.12	0.88	86.46
mountain	3.49	33.29	3.04	29.00	2.73	26.04	2.61	24.90	-0.88	-25.21

Source: Author preparation

Conclusion

Gathering information about land cover change from multi-temporal satellite images helps to understand the nature of such changes, where they are occurring, how much they have and development. Furthermore, the use of remote sensing in combination with GIS technologies is fundamental to analyze and characterize land cover changes. This study was successfully able to detect land cover changes of sacred district area in general and the three hajj places in specific and found that the area of the built-up has increased whereas the area of un-built-up and vegetation has decreased within the period 1998-2013. On the other hand the street network has increased also as a result of the increase in Hajj sites facilities. This work shows that even the event of Hajj is temporary (only one week a year), the land cover is continue changing more and more. Future work with more satellite images and ground truth data may help to map the land cover changes with maximum level of accuracy. Thus, the present study illustrates that remote sensing and GIS are important technologies for temporal analysis and quantification of spatial phenomena which is otherwise not possible to attempt through conventional mapping techniques. Change detection is made possible by these technologies in less time, at low cost and with better accuracy.

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