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Research paper

Monitoring the change in land surface temperature and urban areas using Satellite images. Case study Kafr El-Sheikh City – Egypt

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Abstract: In recent years, the rate of urban growth has increased rapidly especially in Egypt, due to the increase in population growth. The Egyptian government has set up new cities and established large factories, roads and bridges in new places to solve this trouble. This paper investigates the change monitoring of land surface temperature, urban and agricultural area in Egypt especially Kafr EL-Sheikh city as case study using high resolution satellite images. Nowadays, satellite images are playing an important role in detecting the change of urban growth. In this paper, cadastral map for Kafr El-Sheikh city with scale 1:5000, images from Landsat 7 with accuracy 30 meters; images from Google Earth with accuracy 0.5 meter; and images from SAS Planet with accuracy 0.5 m are used where all images are available during the study period (for year's 2003, 2006, 2009, 2012, 2015 and 2017). The analysis has been performed in a platform of Geographical Information System (GIS) configured with Remote Sensing system using ArcGIS 10.3 and ERDAS Imagine image processing software. From the processing and analysis of the specified images during the studied time period, it is found that the building area was increased by 28.8% from year 2003 up to 2017 from Google Earth images and increased by percentage 34.4% from year 2003 up to year 2017 from supervised Landsat 7 images but for unsupervised Landsat 7 images, the building area was increased by percentage 35.9%. In this study, land surface temperature (LST) was measured also from satellite images for different years through 2003 until 2017. It is deduced that the increase in the building area (urban growth) in the specified city led to increase the land surface temperature (LST) which will affect some agricultural crops. Depending on the results of images analysis, Forecasting models using different algorithms for the urban and agricultural area was built. Finally, it is deduced that integration of space-based remote sensing technology with GIS tools provide better platform to perform such activities.

Keywords: Urban area, ERDAS Imagine software, satellite image, LST, ArcGIS 10.3, Forecasting

1. Introduction

Planning and development of urban and agricultural areas have become one of the highest priorities in developing countries such Egypt. Due to inappropriate planning and management, accelerated urban growth and tremendous loss in agricultural land area have become a great challenge for sustainable urban development. Therefore, there is an urgent need to effectively detect and monitor the land use changes and provide an accurate and timely information for planning and development (Ashraf and Alrikabi, 2015). Nowadays, Remote Sensing technologies and GIS, as well as modeling are using to provide an efficient tool in the service of urban management to detect and predict changes, measures and policies affecting the urban future growth planning. Satellite images data can be regarded as a powerful tool for providing the information for land surface temperature, urban and agricultural areas monitoring that can be used by the urban and regional planners and engineers in fraction of the cost and time compared to traditional methods (Ashraf and Alrikabi, 2015).

Malcolm (2003) had investigated using satellite images for geographical applications, offering a reliable tool for decision making in territorial management. He used SPOT 5 satellite images, during the period 1995-2003, which offer the possibility of producing images of large scale territorial areas (60 km by 60 km) with a resolution of 5 m or 2.5 m (Malcolm, 2003). Such resolutions allow interpretations at scales of 1:25,000 and 1:10,000, scales which permit the monitoring of the dynamics of major urban areas. The images would be able to be segmented and classified at different levels. The objects created in this way are linked, in a similar way to a topology in GIS. After analyzing the images using GIS, he found that the percentage of developed land is in relation to the sum of the administrative ambit under consideration the percentage of land developed for each use, as a proportion of the total developed land, quantity of developed land per inhabitant, per household unit and per dwelling unit, household units and dwelling units per km^2 of developed land, quantity of developed land per local job, quantity of land occupied by economic activity per local job and "intensity" of jobs per km^2 of developed land (Malcolm, 2003).

Dontree (2003) had illuminated that changing in the land area for population development has caused change in the land use important environmental destruction. Satellite imageries were used to detect the spatial change of land area, his study benefited from multiple images from MISS1975, ETM 1989, ETM+ 2000, and irs-liss 2007 to study the change in the land use over a period of 32 years (Dontree, 2003). The results indicated widespread land use change in a way that urban land using expanded from 4,878 ha in year 1975 to 19,089 ha in year 2007, as well as applied methods of land use detection were timed consuming and costly, employing multi-temporal satellite images and digital maps have widely gained grounds Dontree, 2003). Ahmadreza (2016) had believed that the growing urbanization increased by 5 billion people by 2030 due to the migration to urban areas over the past decade. Aerial photographs and satellite images with resolution 60 cm have been used to calculate the agricultural land area and the built up area from year 1956 to year 2009. The hybrid model of ca-markov was used to predict the land use changes for the next 50 years with 10-year intervals between 2020 and 2070. The results have shown that if the process of urban growth and land use changes in the areas around the city persist, the urban areas will double by 2070 compared to 2009, while the agricultural lands would decrease in a half (Ahmadreza, 2016).

Ahmed (2011) had studied urban growth in Egypt especially the city of Cairo and its surroundings. The area covered about 600 km^2. The study used satellite images to determine the change in urban area in Cairo during the study period, these images were classified according to images classification. The area of urban areas increased by 17% from 1984 to 2006, the desert land area increased by 5% 1984 to 2006 and the area of the agricultural land decreased by 13% from 1984 to 2006.

Land surface temperature change exerts added stress on urban areas through increased numbers of heat waves threatening people's well-being and, in many cases, human lives (Abduwasit, 2010; Fuqin, 2004). Hakan (2016) used a computer program to calculate land surface temperature (LST calculator) from Landsat images ETM/tm, after analyzing the images, the land surface temperature was calculated from sixth band. LST values ranged from 15 to 40 Celsius degree. Nawal and (2012). had used satellite images from Landsat 7 to calculate the land surface temperatures for a region in Northern Iraq where ERDAS imagine 9.2 software was used. After analyzing the images, it was found that the temperature ranged from 300 to 316 Kelvin.

So, this study aims to evaluate the usefulness and efficiency of using satellite images data to bring out and forecast the change detection in the land surface temperature and growing urban and agricultural area for Kafr El-Sheikh city in Egypt.

2. Study area

Kafr EL-Sheikh City is the capital of Kafr EL-Sheikh Governorate in Egypt and located in the middle of Nile Delta, where it overlooks the Mediterranean Sea Shore in the north and the River Nile (Rashid Branch) in the west. The international coastal highway (which joins all the Mediterranean Sea countries) passes in the north of it. City Kafr El-Sheikh is located on the northern side of the Egyptian border, the latitude and longitude of Kafr el Sheikh, Egypt is: $31°6'42''$ N and $30°56'45''$ E. Kafr EL- Sheikh City lies 140 km north of capital Cairo, 90 km east of Alexandria. Kafr El-Sheikh is famous for agriculture, especially rice, wheat and sugar beet so it is one of the agricultural cities in Egypt. Kafr El Sheikh is responsible for more than 40% of the total sea food production in Egypt (https://ar.wikipedia.org). The study area includes all buildings and roads; open land includes barren, scrub land and residential layouts; agricultural area comprise vegetation and agricultural lands.

3. Available data for the study

This paper utilized more than one data source to get the various necessary information and furthermore think about these sources. The first of these sources is the official cadastral map of the urban plan of Kafr El-Sheikh city at year 2027 with scale 1:5000 knowing 30 ground control points (GCPs) of known coordinates of urban places and geometrically corrected by the Survey Authority in Kafr El-Sheikh. Second, several satellite images from Landsat 5, Landsat 7 and Landsat 8 with resolution 30 m downloaded from site (https://earthexplorer.usgs.gov/) during the research period for years 2003, 2006, 2009, 2012, 2015 and 2017. Thirdly, several images for the studied area (Kafr El-Sheikh city) from Google Earth with resolution 0.5 m (Google Earth program – online program) and from SAS Planet with accuracy 0.5 m for years 2003, 2006, 2009, 2012, 2015 and 2017, (SAS Planet program – online program) as shown in Figures 1 and 2.

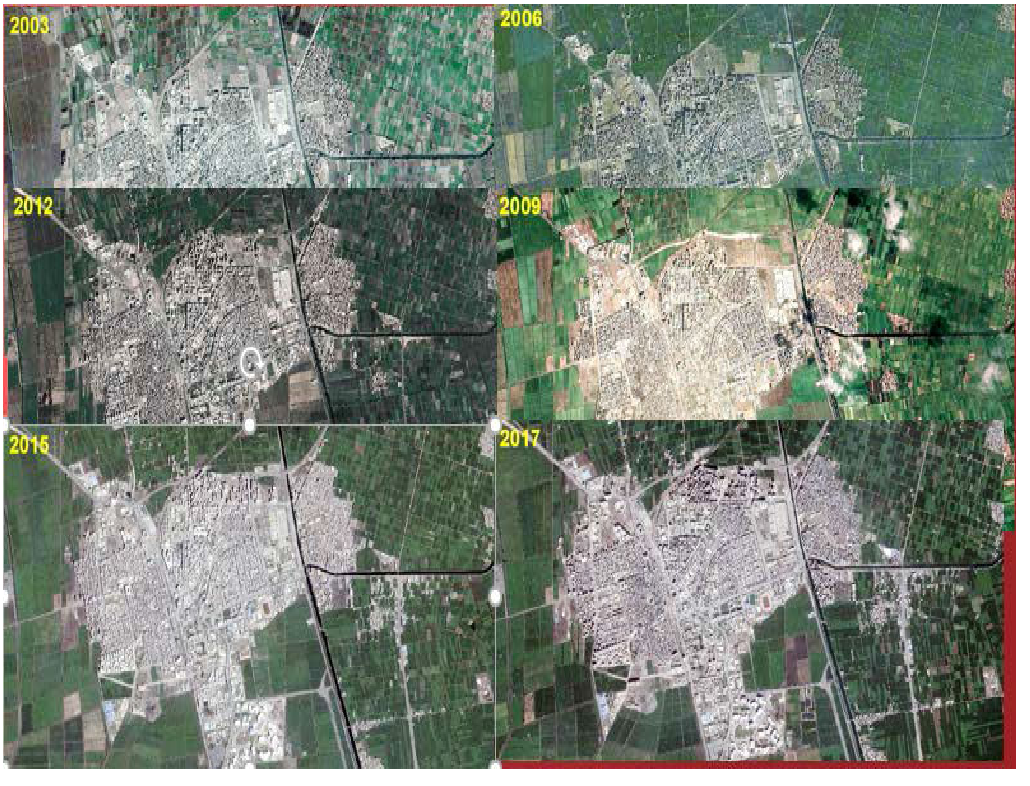

Fig. 1. Google Earth Images for the studied area throughout the studied period years (2003, 2006, 2009, 2012, 2015 and 2017)

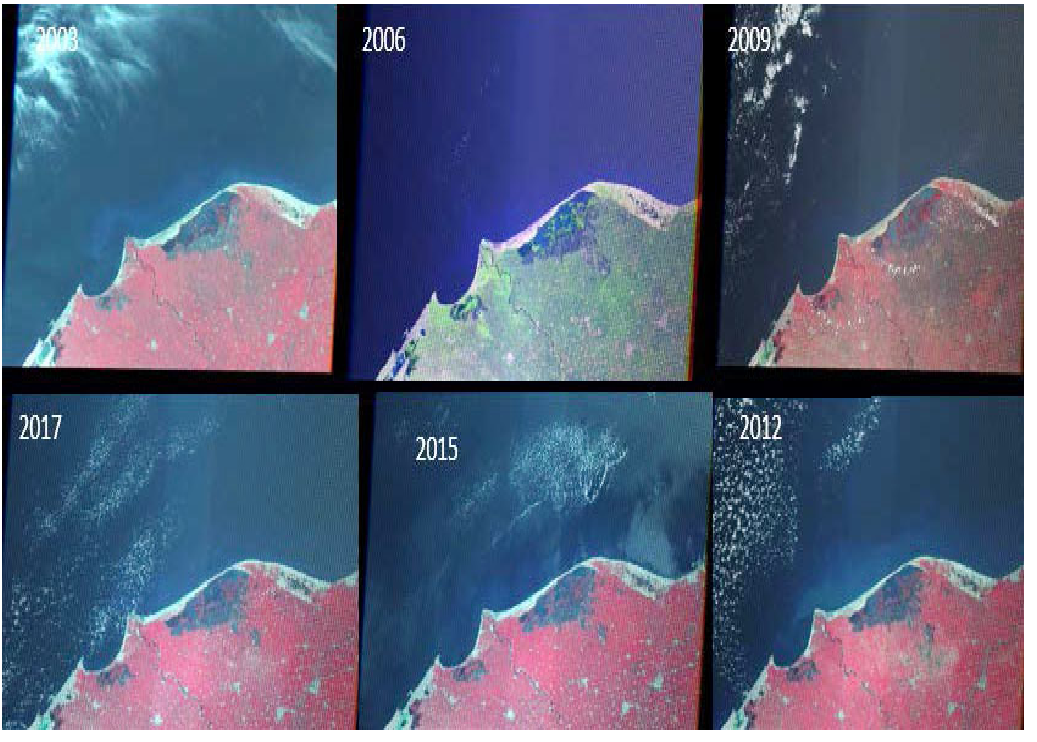

Fig. 2. Landsat 7 images for the studied area throughout the studied period years (2003, 2006, 2009, 2012, 2015 and 2017)

4. Methodology of the study

Figure 3 shows the study plan and the analysis steps depending on the downloaded images for the specified study period using a platform of Geographical Information System (GIS) configured with Remote Sensing system using ArcGIS 10.3 and ERDAS Imagine image processing software.

4.1. Image processing and analysis

The cadastral map (hardcopy map) was scanned and georeferenced using only 20 ground control points (GCPs) of known coordinate's values using ArcGIS 10.3 software but the remaining known coordinate's points were taken as check points (validation process). The corporation map of the study area was georeferenced through image to image registration. Locations which can be identified in both map and corporation map such as road intersections, railway crossings were considered during the process of "image to image registration".

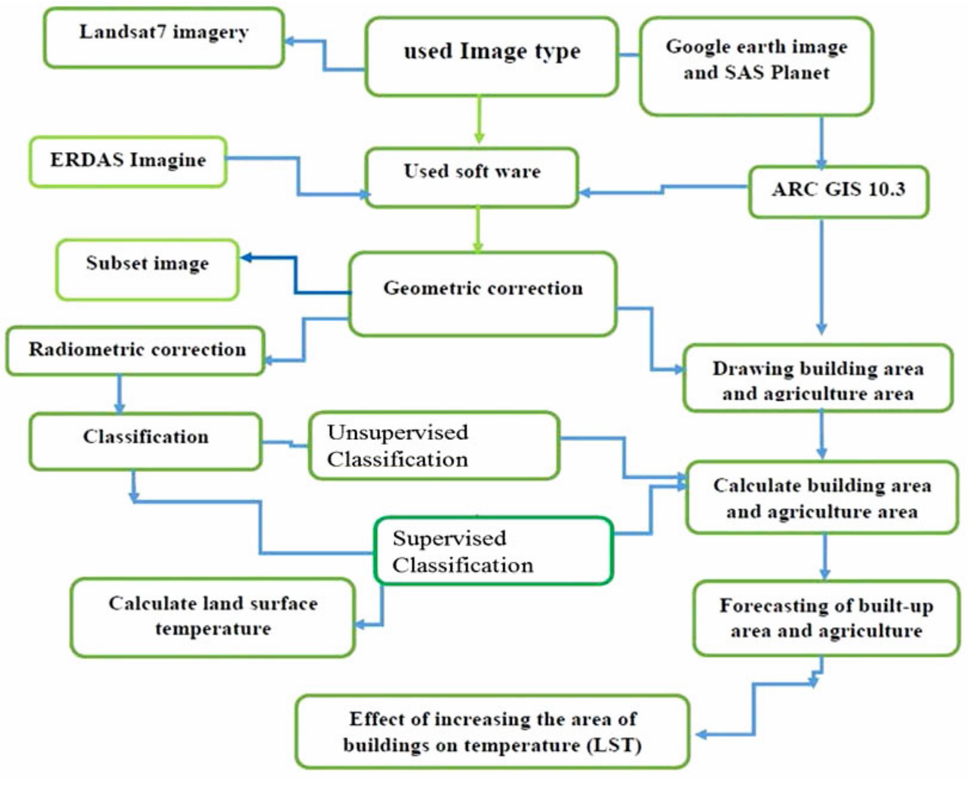

Fig. 3. Methodology of Study

4.1.1. For Google Earth images

An important advantage of Google Earth is that it provides images taken at different time periods which can be used by the urban planners to perform landuse change detection analysis. The Arc Map10.3 program was used to correct the images and extract the required data to calculate the agricultural land area and calculate the area of the buildings over the different periods. The cadastral map (hardcopy map) was scanned and georeferenced using only 20 ground control points (GCPs) of known coordinate's values using ArcGIS 10.3 software and the remaining known coordinate's points were taken as check points. The boundary is digitized, then it has been converted from ArcGIS shape file format (.shp) to Google Earth compatible format (.kml).This rectified image can be used for rectifying other images (by: Georeferencing image from corrected image).

After the geometric correction of all images, the agricultural land area and the buildings area were calculated using the ArcGIS program throughout drawing the residential block on the specified image. The change detection was carried out also using ERDAS Imagine image processing software as shown in Figure 4 and Figure 5.

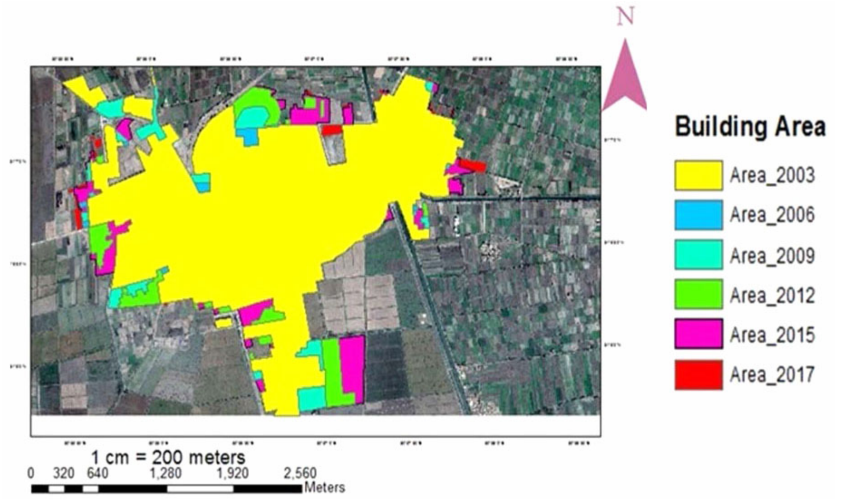

Fig. 4. Change detection of building areas for the studied years from Google Earth images analysis

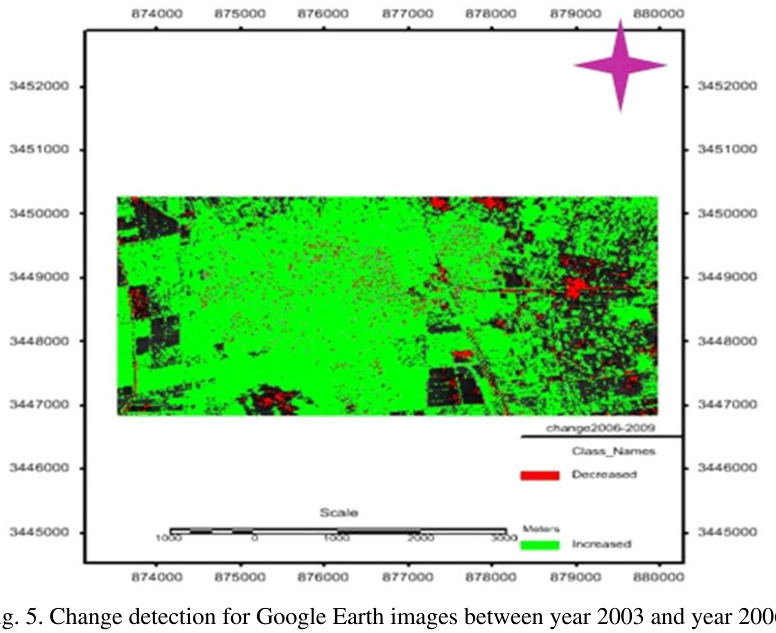

Fig. 5. Change detection for Google Earth images between year 2003 and year 2006

4.1.2. For Landsat images

The uploaded Landsat 7 images are 9 bands, then these bands are converted into image using EARDAS Imagine program throughout choosing raster menu then choosing layer stack for years (2003, 2006, 2009, 2012, 2015 and 2017). Images are corrected using the ARCGIS 10.3 program by inserting a corrected image. These images are uploaded to the North Delta region so it is necessary to define the study area on this map by subset the study area using the ARCS GIS program. ERDAS imagine 2014 program was used to extract the required data. Image contains gaps which were divided into segments, so these lines must be removed by selecting raster menu then selecting spatial menu finally selecting focal analysis as shown Figures 6a, 6b.

a) Focal gaps b) Focal gaps removed

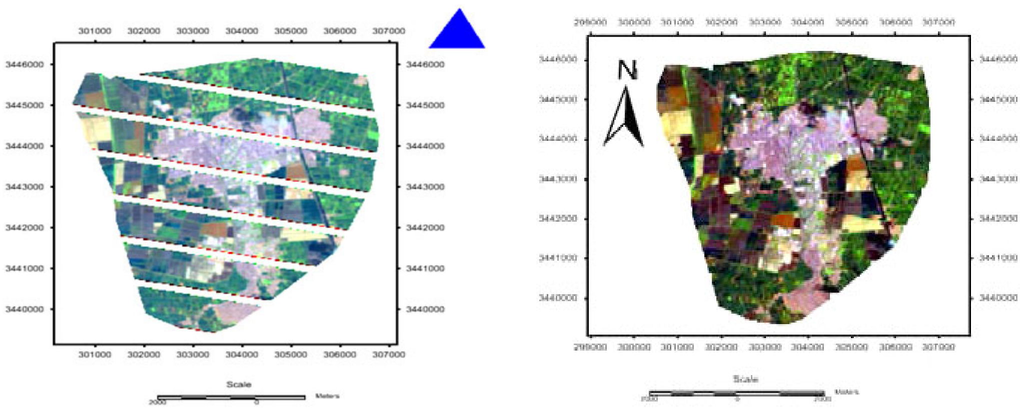

Fig. 6. Focal gaps analysis for Landsat 7 image at year 2009

The program worked to separate the convergence colors in the base so that it facilitates the control of each color and increase the range between the smallest value and the largest value and worked to adjust the general contrast of the image which can be considered a statistical methods to increase the difference in image contrast and to enhance the image display.

4.2. Classification

Classification was the method of sorting pixels into a limited number of individual classes, or classifications of data based on their data file values. If a pixel contents a certain set of criteria, then the pixel was assigned to the period that corresponds to that criteria. There were two methods to classify pixels into changed categories:

Supervised classification was more closely organized by you than unsupervised classification. In this method, you select pixels that characterize patterns you know or that you can classify with help from other sources. Information of the data, the classes wanted, and the algorithm to be used was necessary before you begin selecting teaching samples. By classifying patterns in the images, you could train the computer system to detect pixels with like characteristics. By location priorities to these classes, you supervise the classification of pixels as they were given to a class value. If the classification was correct, then each resulting class corresponds to a design that you originally recognized. This section shown how the Supervised Classification tools allowed you to control the classification process as shown Figure 7.

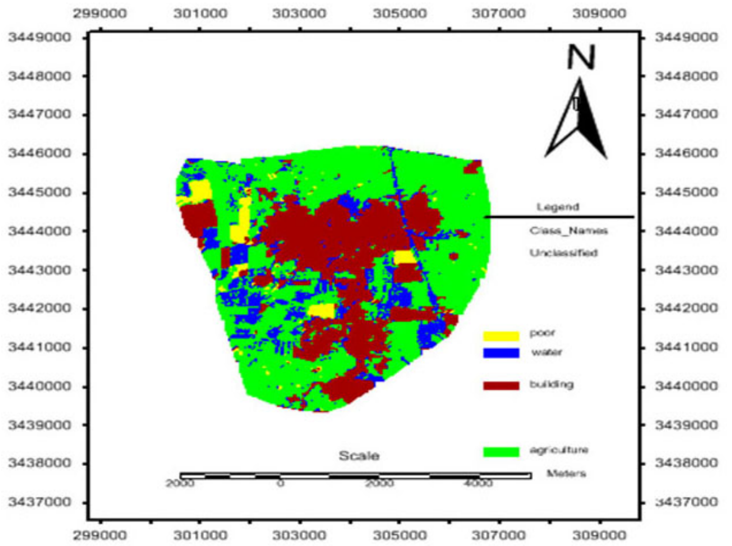

Fig. 7. Supervised classification of Landsat 7 image at year 2003

Unsupervised classification was more computer-automated. It allowed you to identify parameters that the computer used as guidelines to uncover statistical patterns in the data. In this tour monitor, you perform both a supervised and an unsupervised classification of the same image file as shown Figures 7 and 8.

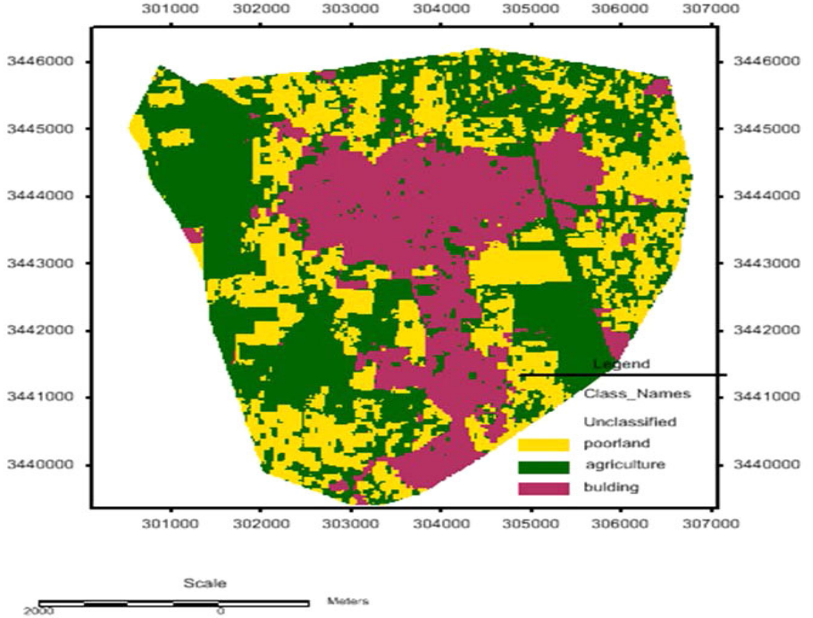

Fig. 8. Unsupervised classification of Landsat 7 image at year 2003

The overall accuracy for urban land use periods of 93.4% was reached. The classification was especially successful on the image from the year 2003, but in overall urban administrative and land use gave good classification results. The main errors were from the confusion between residential and urban organizational region in all classifications. Accuracy assessment for supervised classification of Landsat 7 images at several years is given in Table 1.

Table 1. Accuracy assessment for supervised classification of Landsat 7 images at several years

Classes	Accuracy assessment of supervised classification of Landsat 7 images at year %					
	2003	2006	2009	2012	2015	2017
Urban area	92	89	95	94	96	93
Agriculture area	88	93	96	98	94	97
Over all accuracy	90	91	95.5	96	95	95

5. Results and analysis

5.1. For monitoring the urban area changes

From processing and analysis the satellite images downloaded from Google Earth and Landsat 7, the building and agricultural areas for the studied city in the specified years were calculated for three cases (Google Earth images, supervised and unsupervised Landsat 7 images). The results are shown in Table 2 and Figures 9a, 9b.

Table 2. Resulted agricultural and building areas in hectares for all images types for studied years

Type of images	Area in hectare	Year classified					
		2003	2006	2009	2012	2015	2017
Google Earth image	Agricultural area	1745.4	1740.7	1708.8	1669.1	1625.4	1616.2
	Building and poor area	479.3	484.6	515.4	555.6	599.1	617.8
Supervised classification for Landsat 7 images	Agricultural area	1760.4	1712.5	1701.2	1650.3	1611.4	1599.7
	Building and poor area	464.3	512.6	524.2	574.6	614.7	624.2
Unsupervised classification for Landsat 7 images	Agricultural area	1750.5	1719.6	179.4	1638.9	1601.4	1581.2
	Building and poor area	474.6	504.2	513.7	585.1	623.9	645.1

As shown in Table 2 and Figure 9, it is deduced that:

1. The building area throughout the specified period was increased by 1.385 km^2 from year 2003 up to 2017 from Google Earth images by percentage 28.8% and increased by 1.599 km^2 from year 2003 to year 2017 from supervised Landsat 7

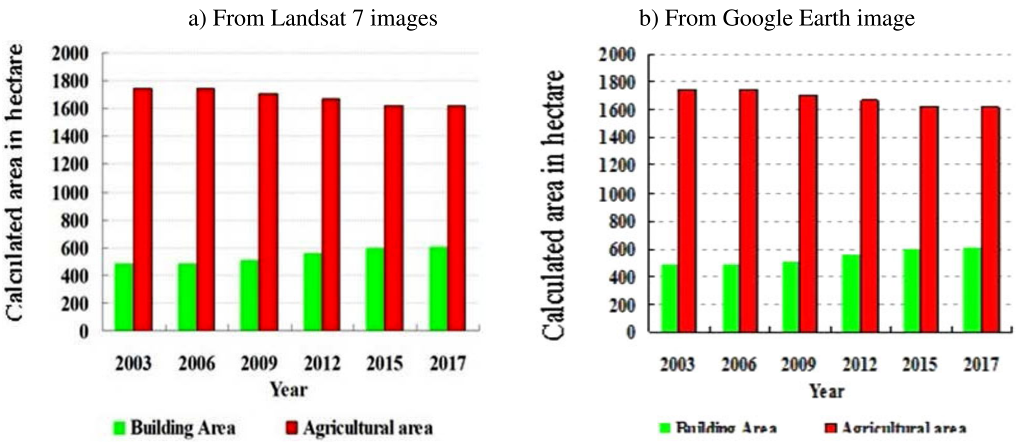

Fig. 9. Decreasing in agricultural area and increasing in building area for the studied years

images by percentage 34.4% but for unsupervised Landsat 7 images, the building area was increased by 1.705 km^2 by percentage 35.9%.

2. The agricultural area throughout the specified period was decreased by 1.292 km^2 from year 2003 up to 2017 from Google Earth images by percentage 7.4% and decreased by 1.607 km^2 from year 2003 to year 2017 from supervised Landsat 7 images by percentage 9.1% but for unsupervised Landsat 7 images, the agricultural area was decreased by 1.693 km^2 by percentage 9.7%.
3. The differences between the resulted building and agricultural areas from Google Earth images, supervised and unsupervised Landsat 7 images are clear. The average difference for all specified years between the resulted building area calculated from Google Earth images and supervised Landsat 7 images is 5.9% but for the agricultural area is 1.6%. The average difference for all specified years between the resulted building area calculated from supervised and unsupervised Landsat 7 images is 1.4% but for agricultural area is 0.6%.

5.2. For monitoring land surface temperature changes

Kafr El-Sheikh is an agricultural city of the first class, with its location and fertile soil. The city was famous for its cultivation of rice, fish and sugar beet, and because of the observed boom in the urban crawling of the agricultural lands, it led to a rise in the surface temperature. Therefore, it was necessary to calculate annual temperatures during the study period from satellite images during September using different programs (ERDAS Imagine, Envi and ArcGIS) by introducing an equation of heat into the program used (ARC GIS) (Hakan, 2016).

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_T}\right) + 1} \tag{1}$$

Table 3 shows the temperature values resulted from satellite imagery and also the temperature values from world weather site (https://www.weathersuccess.com). It is seen that there is a difference between the two sources. By knowing the temperature resulting from image analysis it was observed that the average temperature increases from 2003 to 2017 is 5°C as shown in Figure 10 and the average annual increase in temperature is 0.35°C.

Table 3. Comparison of Land Surface Temperature (LST) resulted from Landsat 7 images analysis and world weather site for the specified study period

Data source	LST in °C	Year					
		2003	2006	2009	2012	2015	2017
From Satellite images analysis	Max.Temp	36.66	37.03	35.9	32.2	38.27	39.48
	Average. Temp	*29.52*	*28.52*	*29.52*	*29.52*	*28.5*	*29.5*
	Min. Temp	18.38	24.12	20	18.38	24.36	25.33
From World Weather Site (www.weathersuccess.com)	Max. Temp	34	33	32	33	34	32
	Average. Temp	*27*	*25*	*26*	*25*	*27*	*26*
	Min. Temp	20	21	20	19	21	21

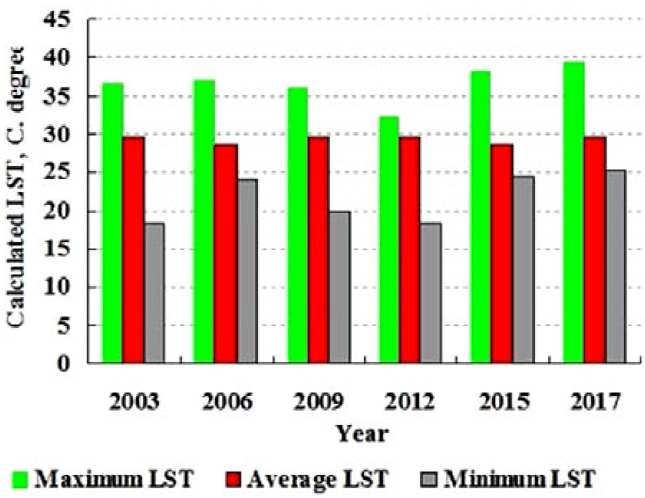

Fig. 10. Change in Land Surface Temperature (LST) resulted from Landsat 7 images processing

Through the analysis of images, it was observed that the temperature values are different from that recorded on the weather sites this is because that the result of the presence of multiple phenomena in the images affect the calculation of temperature and also the applied equation by which the temperatures calculated.

5.3. Forecasting the urbanization in the study area

Forecasting, as general, is the process of making prediction of the future depending on past and present data and most commonly by analysis of trends. Forecasting refers to statistical methods employing time series, cross sectional or longitudinal data, or alternatively to less formal judgmental methods and is applied estimation of some variables of interest at some specified future date. Risk and uncertainty are central to forecasting; it is generally considered good practice to indicate the degree of uncertainty attaching to forecasts. In any case, the data must be up to date in order for the forecast to be as accurate as possible.

Quantitative forecasting models are used to forecast future data as a function of past data. These methods are usually applied to short- or intermediate-range decisions. Previous research shows that different methods may lead to different level of forecasting accuracy.

Depending on the resulted urban and agricultural areas from Google Earth images and Landsat 7 images analysis for the specified time period, several mathematical algorithms were applied to fit and find the relationship between the years (as an independent variable) and urban area (as a dependent variable) using least squares estimation and also to forecast the value of urban areas in the future. The applied mathematical models were linear, Polynomial (2^{nd} degree and 3^{rd} degree), exponential and logarithmic functions Figure 11. Comparison of the resulted urban area from forecasting model and the calculated urban area from official cadastral map at year 2027 was done. Forecasting value for urban area at year 2027 for the studied area will be 745.4 Hectar from supervised classification Landsat 7 images but it will be 770.5 Hectar from unsupervised classification images using Linear forecasting model. But for agricultural area, the forecasting value is 1478.8 Hectar from supervised classification Landsat 7 images and 145.305 Hectar from unsupervised classification images using linear forecasting model.

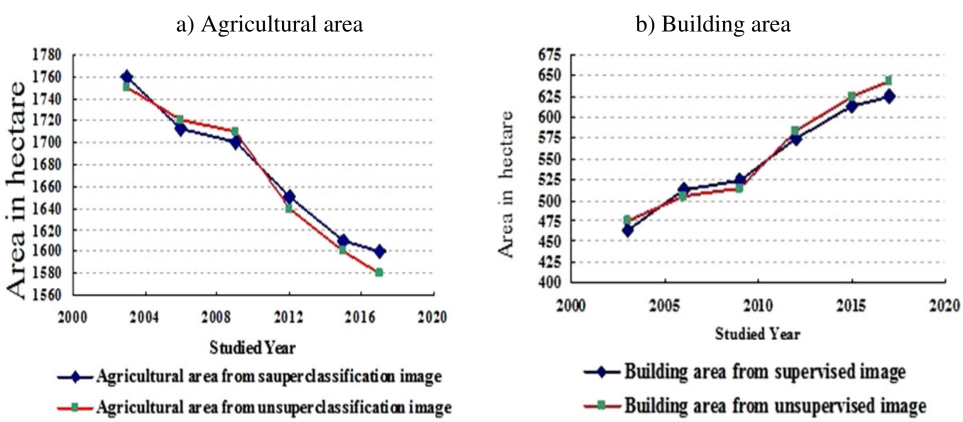

Fig. 11. Relationship between years of study period and resulting agricultural and urban areas

To compare all the techniques applied in this paper for forecasting the building area and get the optimum model applied, the mean value of correlation coefficient for all

Google Earth images and Landsat 7 images analysis for all applied techniques are presented in Table 4.

From the results arrived in Table 4, it is clear that linear and polynomial models in this case gets the best values for correlation coefficient rather than any other models.

Table 4. Correlation coefficient for all forecasting models for building areas

Model Function	Correlation Coefficient (R)		
	From Google Earth images	From supervised Landsat 7 images	From unsupervised Landsat 7 images
Linear	0.9715	0.9804	0.9637
Polynomial 2^{nd} degree	0.9776	0.9805	0.975
Polynomial 3^{rd} degree	0.9801	0.9808	0.9815
Exponential	0.9664	0.9776	0.9682
Logarithmic	0.9712	0.9801	0.9635

5.4. Relationship between urban area changing and land surface temperature variation

This section attempted to evaluate the effects of urban growth change on the land surface temperature (LST) variation for Kafr El-Sheikh city. For the study area throughout the study time period, the urban areas and LST (maximum, average and minimum values) are calculated from Landsat 7 images analysis. The relationship between the resulted building areas in hectare and LST derived from Landsat 7 image analysis was constructed as shown in Figure 12.

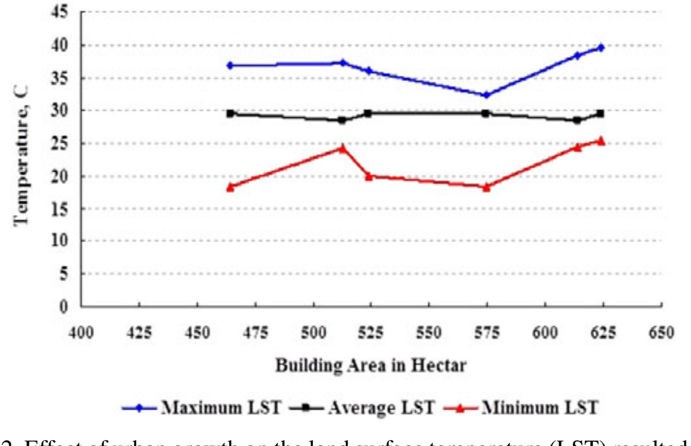

Fig. 12. Effect of urban growth on the land surface temperature (LST) resulted from Landsat 7 images analysis

It is deduced that the effects of urban growth on the LST change of the study area were very limited because the smaller areas of the urban growth trajectories would generate a limited LST change contributions.

6. Conclusion

Based on the images analysis and obtained results, the following conclusions can be summarized.

1. Satellite imagery is one of the most important and effective sources that reveal and identify the changes in urban and agricultural areas, and also the land surface temperature changes.
2. Geographical Information System (GIS) configured with Remote Sensing system using ArcGIS 10.3 and ERDAS Imagine image processing software can be effectively used correction and analysis of the satellite images and also used in the process of environmental analysis (LST calculations).
3. Urban change has become one of the most important changes that occur in the region, especially in Kafr El Sheikh city due to the large number of population and migration of rural people to Kafr El Sheikh City. Urbanization in the study area increased by 28.8% from year 2003 up to 2017 from Google Earth images and increased by percentage 34.4% from year 2003 to year 2017 from supervised Landsat 7 images but for unsupervised Landsat 7 images, the building area was increased by percentage 35.9%, and in some areas has altered the structure and spatial pattern of the city. The results demonstrated that the average deviation degree of urban growth trajectories was much greater than that of the existing urban trajectory.
4. The agricultural area throughout the specified period was decreased by percentage 7.4% from year 2003 up to 2017 from Google Earth images and decreased by percentage 9.1% from year 2003 to year 2017 from supervised Landsat 7 images but for unsupervised Landsat 7 images, the agricultural area was decreased by percentage 9.7%.
5. From computing land surface temperature for the studied area, Arc Map program is better than ERDAS Imagine program. Analysis of the impact of urban growth on land surface temperature variations shows that the urban sprawl has a minimal impact on land surface temperature in the city.

As a recommendation from the study, it is noticed that a significant decrease in the area of agricultural land and a significant increase in the building area because the revolution of 25 January, where the low was absent for period of time which led to the encroachment on agriculture land and the encroachment also on state property from 2011 to 2014. So, the agricultural land must be protected from crawling and the maximum penalty should be imposed on those who infringe upon it since it is considered the food source for all the members of the country.

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