Assessing the Impact of Urban Encroachment on Agricultural Land in Kafr El-sheikh Governorate using GIS and Remotely Sensed Data

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Abstract

Urban encroachment is one of the top challenges facing developing countries due to the expansion of unplanned constructions. It is associated with increment in basic services including water, electricity and sewage. Nowadays in Egypt, lack of monitoring and governmental control on new constructions causes environmental problems, threatens the current infrastructure and may lead to problems in food security. Remote sensing and GIS are effective tools to map and analyse urban encroachment using Landsat images which provide needed data for measuring the change in urban area during the period of study. The aim of this study is to estimate the changes in agricultural area due to urban encroachment in Kafr El-sheikh Governorate, Egypt by using remotely sensed Landsat multispectral images for the period between the years 2010 to 2016. Software (ERDAS IMAGINE 2014 and ArcGIS 10.3) has been used for processing and analysing remote sensing data. Results concerning the agriculture land revealed that two main issues were developed during this period. First, a loss of 77.2 km² (about 3.1% of total fertilized land in Kafr El-sheikh Governorate) is due to urban encroachment from illegal construction of settlements and fish farms. Second, an increase of more than 20 km² is due to land reclamation in non-developing areas, around the northern part of Lake Burullus and eastern part of the study area. Agriculture and fishing sectors, which present the first and largest economic sectors in the study area need to get more attention from the Government because these are most influenced and damaged sectors by urban encroachment. Our study recommends conducting further studies investigating the urban encroachment for the whole region using remote sensing data and GIS tool. Furthermore, in order to prevent the illegal constructions, the application of law in Egypt has to be enhanced and the essential services has to be provided for the increase in the development of rural areas.

Keywords: Land cover change, urban encroachment, remote sensing, GIS
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1. Introduction

The global population has grown dramatically during the last century. Meanwhile, we have witnessed an unprecedented concentration of population into urban places around the world. Urban sprawl became a global phenomenon in both developed and developing countries [1]. Urban encroachment is not just a manifestation of a population explosion and demographic change, or even of the vast impersonal forces of globalization, it is a result of failure of national and urban housing policies and laws delivery. People who live in unplanned settlements lack the essential services and face several problems such as environmental, planning, health and social problems [2].

Most urban sprawl studies focused on the relationship between urbanization and environmental change in developed countries but there is a need for efforts to treat these questions in developing countries. This study approached to understand the current and future trends of urban growth in Alexandria, Egypt by using remote sensing and GIS techniques. One of the most important findings in this study area is the loss of cultivated land in favor of urban expansion [3]. Many studies [4-6] used multi-temporal remotely sensed data to study the change in land cover and land use and its impacts on agriculture areas. These studies concluded that urban encroachment regularly occurs through the deduction of agriculture land.

The cultivated areas in the Nile Valley and Delta are suffering from a serious problem of urbanization. This problem has caused an irretrievable loss of very fertile suitable soils. The problem is characterized by a very severe status and rate while the risk is severe. Shalaby [7] used remotely sensed data (Aerial photographs) for assessing the environmental condition of the study site. Another study [8] presented the effects of urban encroachment onto previously cultivated lands "urbanization". The researcher found that the expansion of thousands of small villages around the agricultural lands represents a risk that leads to loss in the agricultural productivity and degradation of water quality. Change detection has to be studied in order to determine the change in land cover, understanding the relationship between the human and environment and to use this information in better environmental management.

The Egyptian Northern Lakes have been major areas of fish production in Egypt. The fishing sector in Egypt is affected by urban encroachment caused by the violation of water resources from building illegal fish farms around Lake Burullus and Rosetta branch. Another type of violation from urban encroachment is drying-up the borders of Lake and Rosetta Nile branch to expand land area that causes a decrease in the total area of Lake. In addition, illegal fish farms are classified as a pollutant source because of the nutrients and generated wastes from this activity which causes changes in the ecosystem [8].

Nowadays, urban encroachment is an ongoing problem that has to be faced in Egypt. It has an impact on our daily life. Kafr El-sheikh Governorate was taken as a study area to assess the urban encroachment impact on its agricultural land. The aim of the study is to measure the changes in agriculture land resulting from urban encroachment by using remotely sensed data and GIS tools.

2. Materials and Methods

Kafr El-sheikh Governorate, a part of the Nile Delta, is one of the oldest intensely cultivated areas in Egypt. The governorate has a total population of about 3.3 million inhabitants [9]. It includes a variety of environmental habitats: Burullus Bay, Lake Burullus, Nile branch and the adjacent agricultural, urban and coastal area. The study area is located in the northern part of the Nile Delta, extends from 30° 59′38″ to 31° 36 ′00″ Latitude and from 30° 21′40″ to 31° 18′40″ Longitude. The governorate bordered from north by the Mediterranean Sea, with about 100 km of coastline, from

the south by Gharbeya Governorate, from the east by Dakahleya Governorate and from the west by Rosetta city where the Rosetta branch of the River Nile flows into the sea (Figure 1.).

Kafr El-sheik Governorate covers a total area of about 3754.121 km^2 including 10 districts, 11 cities, and 69 rural local units which consist of 143 villages, in addition to Manzala lake (about 600 km^2). According to the Central Agency for Public Mobilization and Statistics, 76.1% of the Kafr El-sheikh Population governorate lives in rural areas, which represents 81% of the total number of residential buildings. The rest of the population (23.9%) lives in urban areas, which presented 19% of the total number of residential buildings. That explains the sweep of the form of rural building in Kafr El- sheikh Governorate [9]. Most of the study area can be classified as cultivated land, which covered about 2310 km^2 (more than 66% of the total area). The area is famous for producing rice, beets, wheat and cotton. The nature of the area helps in maintaining three main activities: crop, animal and fish production [10]. Due to unplanned building extension new environmental burdens took place. Figure 2 presents onsite photos of water pollution in boundaries of Lake Burullus on 30 March 2018.

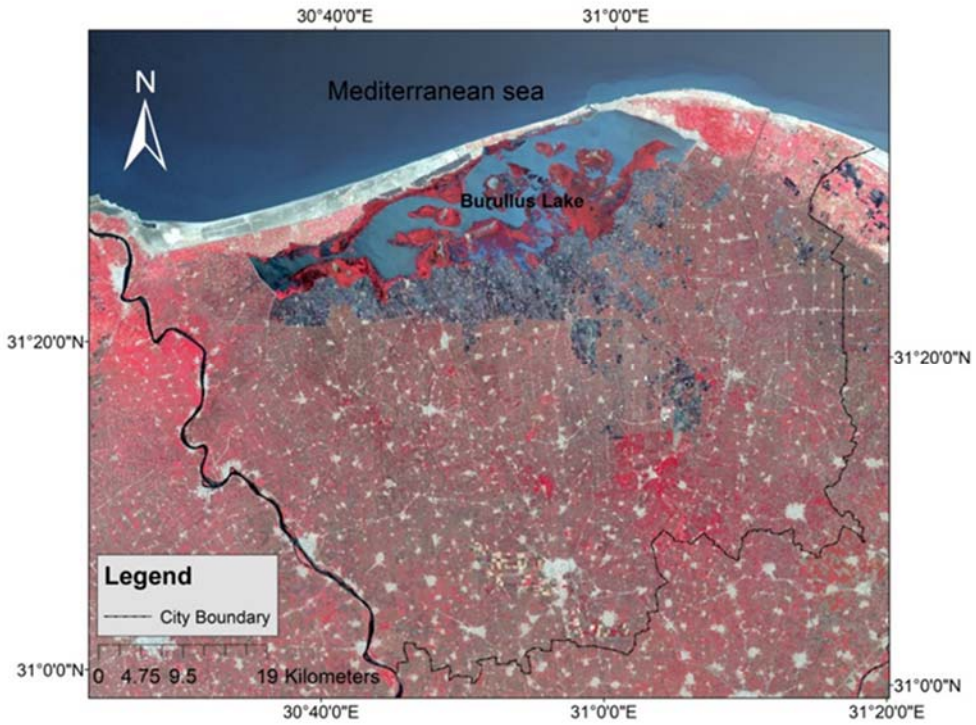

Figure 1. The location of study area

Figure 2. Violation of building around Lake Burullus

Loss of agriculture land from urban encroachment has been measured by available remote sensing data. Landsat 8 and Landsat 5 image (path 177, row 38, covering Kafr El-sheikh City) acquired on 19 Sep, 2016 and 18 Aug, 2010. These dates were the closest available data for the same agricultural season. Comparison between images dated in years 2010 to 2016 was chosen, as 2010 represents the status of the area before the political instability of the country in 2011 when most of illegal law violation of the lands happened. As for 2016 image, it was the most recent available image of the area clear with zero clouds.

Applied framework of methodology is presented in Figure 3. A polygon of Kafr El-sheikh Governorate boundary was used to clip the study area from the satellite images. This polygon was the last database updated of Central Agency for Public Mobilization and Statistics.

After clipping study area, Normalized Difference Vegetation Index (NDVI) was used for illustrating vegetation areas in both of images by using equation NDVI = (NIR - Red) / (NIR + Red). This index depends on visible and near-infrared bands of the electromagnetic spectrum for determining the density of green area on a patch of land [11]. The index produced an image with a highlight on vegetation area, which gained a positive pixel value and the other phenomenon gained pixel value less than or equal zero. By using conditional equation, vegetation areas have been extracted from NDVI index as it can be seen in Figure 4. Values of vegetation and non-vegetation areas have been recoded and giving numbers: 1 for vegetation and 0 for any other phenomenon. These steps were done for both images.

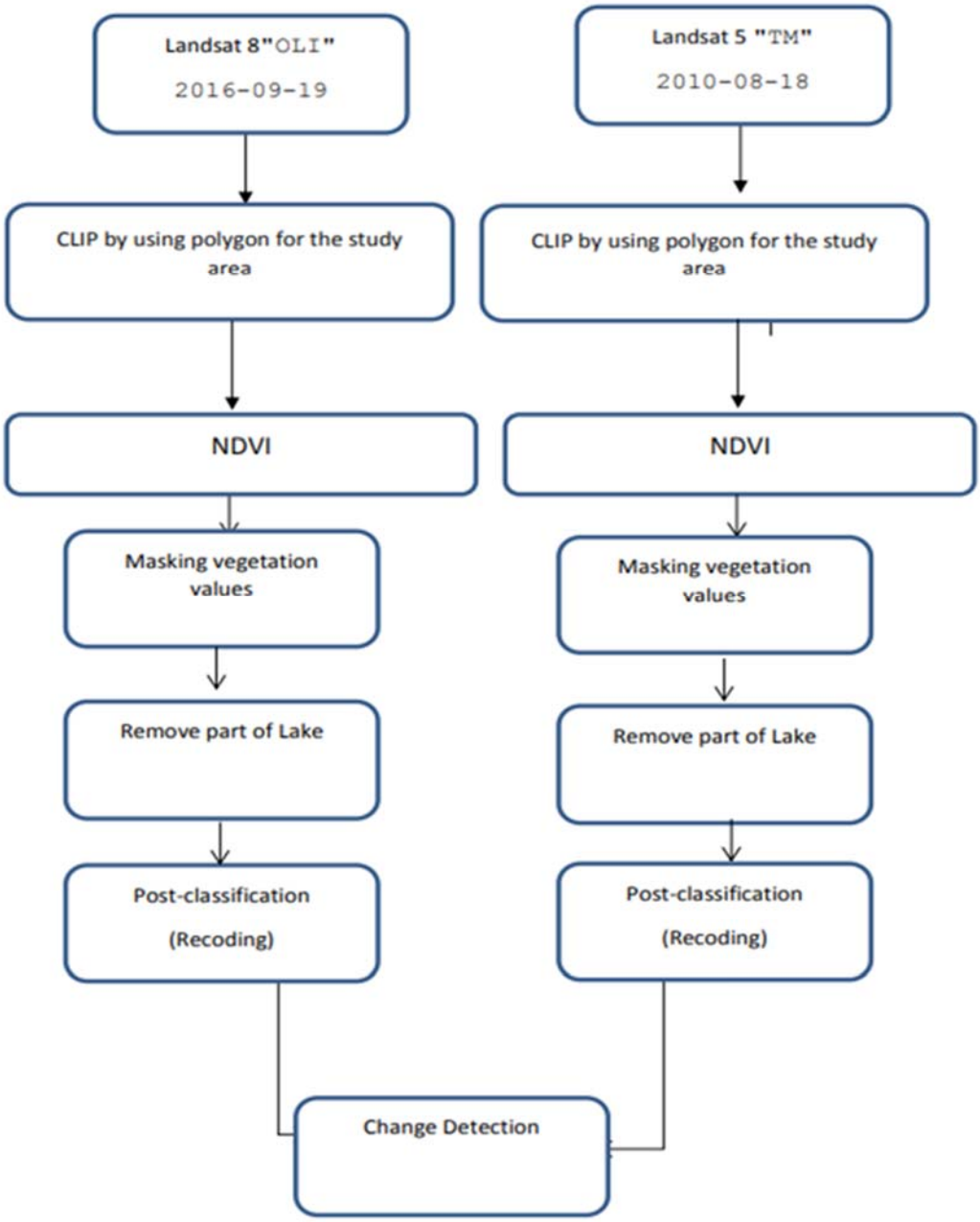

Figure 3. Framework of applied methodology

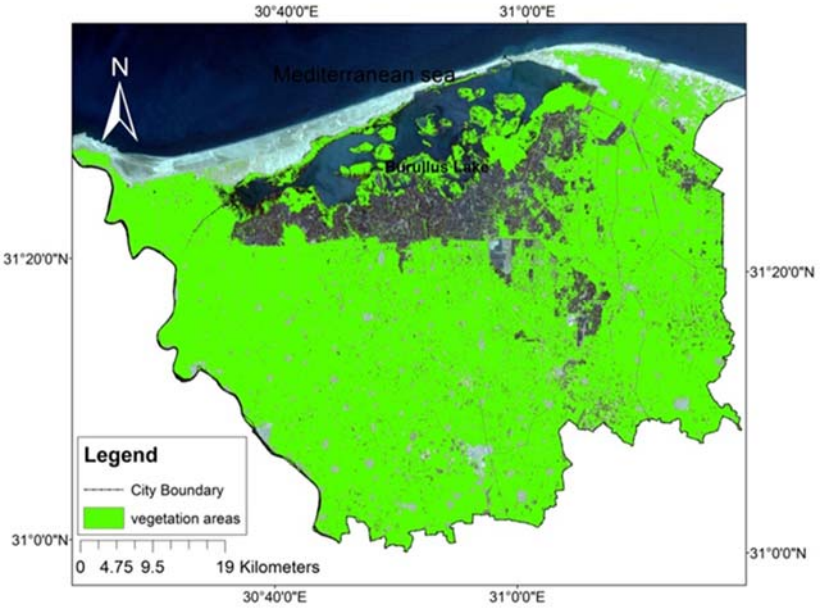

Figure 4. Extracting vegetation areas from NDVI index

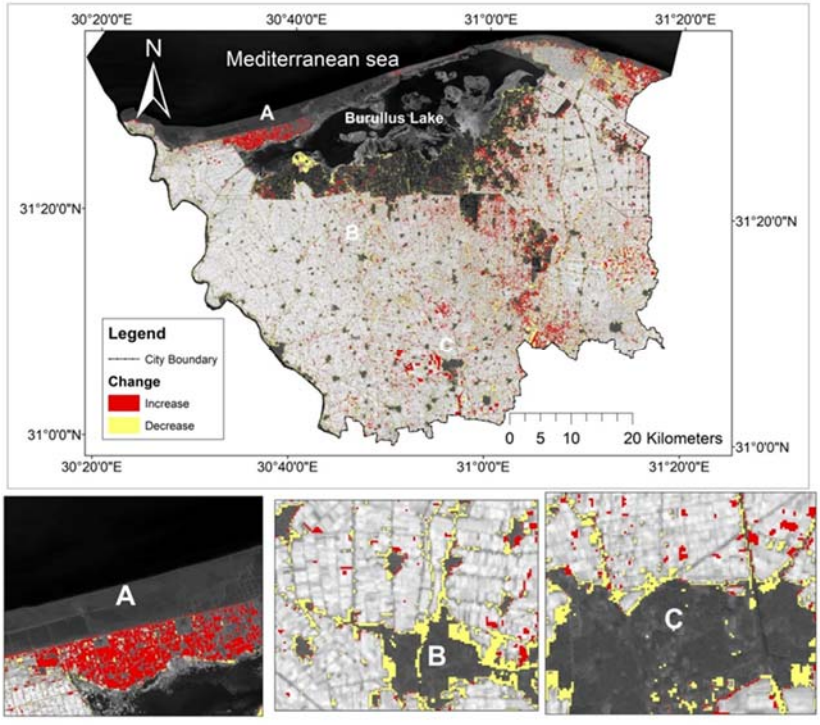

Figure 5. Changes in agricultural area between 2010 to 2016

Lake Burullus has a huge area of plants that does not include search objective because the essential goal is emphasized on cultivated areas, so the lake area has been masked from both images to increase the accuracy of results. There is interference between built-up land and soil land, thus both lands would be classified as agriculture land because both have the same purposes. Recode step has been done for merging soil lands with agriculture lands to be in the same class. The main goal from this step was to increase the accuracy of data, which reflected on the results. The last step is to detect the change between both images by using a subtraction equation, which produced an image illustrating increase and decrease areas.

The accuracy of the land cover classification has been measured by using ground truth data for the results. A stratified random sampling technique was applied for collecting the ground truth data for accuracy assessment. In this technique a minimum number of samples points was 100 for each image. The overall accuracy is determined by the sum of all samples on the diagonal divided by the total number of samples. The accuracy of both post classification images is 97% for 2016 image and 95% for 2010. The resulted accuracy of images is acceptable for the goal of study [12].

Figure 4 shows the vegetation cover of the study area (highlighted in green). In this step extraction of vegetation areas was done using NDVI index. This method is helpful for concentrating on assessing vegetation cover and removing other land cover features in the study area, which helps to increase the accuracy of the data for vegetation cover [11]. There was an overlapping between bare soli and urban land. For solving this problem, reclassifying step (recoding) was used to add soil lands to vegetation cover and that was the last step before change detection.

3. Results and Discussion

The changes in agricultural land during the period from 2010 to 2016 have been presented in Figure 5. In area (A), an increase of about 20 km² took place in the north part of Lake Burullus and other places around the lake due to agriculture reclamation. These areas are concentrated in the north part of the Lake and the eastern part of the study area. In areas (B) and (C), an excessive rate of deterioration of vegetarian cover equal about 3% of area of the study area was detected. This deterioration is concentrated around the villages and both sides of the road. The loss of agricultural land accorded not only due to urban encroachment but also due to increase of illegal fish farms. By subtracting the difference between the increase and decrease of agriculture land from the two satellite images in the period of 2010 to 2016, it was found that about 77.2 km² is the total decrease in the agriculture land of the study area. This area represents about 3.1% of total fertilized land in Kafr El-sheikh Governorate.

A previous study [13] assessed urban sprawl on agricultural soil of northern Nile Delta of Egypt by using remote sensing and GIS tools during the period between years 1984-2006. They concluded that about 689.20 km^2 of the total urban area (6.3% of total area) increased, while about 247.14 km^2 (2.26 % of total area) from agriculture land was lost during the study period. Another study [14] used GIS and remote sensing tools to monitor urban growth and land use change detection in Daqahlia Governorate during the period of 1985-2010. These results showed that about 33% of the total agricultural land was lost and about 30% of built-up area increased in the study area during the study period.

According to the results of the study, the following should be taken into consideration:

1) Urban Planning agency should cover preserve agricultural land from further urban encroachment by restricting and avoiding further expansion of the built-up area to protect agriculture sector.

2) Urban Planning agency should be concerned to develop rural areas and preserve the agriculture character. This will support agricultural area because it will increase the profit from

agriculture production for farmers, which will make farmers more concern for protecting their cultivated land.

3) GIS and remote sensing proved to be efficient tools for assessing urban encroachment. Landsat images were also efficient for studying land cover change in a big area like Kafr El-sheikh. Future studies can be conducted by using these tools with recent remote sensing images and updated data for similar studies.

4) The same methodology can be employed for investigating land cover change for other areas in Egypt, especially in the Nile Delta region.

5) The violations of illegal constructions of buildings, and fish farms that leads to urban encroachment should be abstained by enhancing the application of law in rural areas and activating strict regulations to maintain them.

4. Conclusions

Remote sensing and GIS were employed using satellite images from 2010 to 2016 to classify and analyze dramatic changes of agriculture areas. It was found that the about 3% of one the most fertilized lands of Egypt were lost between 2010 and 2016 due to urban encroachment by buildings constructions and illegal expansion of fish farms in Kafr El-sheikh. This lost not only represents a problem in food security but also has environmental and social dimensions as water pollution levels increased in Lake Burullus and limited social services are available in the expanded areas. Moreover, the new building could threaten infrastructural corrosion and its ability in absorbing the growing population which results from the new buildings that were built without planning. After the dramatic change in Egypt during 2011, the country lost a huge area of agriculture land due to several illegal violations. In order to identify the current status of these violations and find out their impacts in order to develop proper solutions further research studies are recommended by continuing studies for the whole region by remote sensing techniques using satellite imagery for monitoring urban encroachment of the study area.

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