Dilemma of Vibrant City and Endless Urban Growth, Lessons from Alexandria, Egypt

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1 ABSTRACT

Urban planners and visionary leaders always have dreams of designing and establishing new vibrant cities or making new history by regenerating old cities. When the city (new or revived) starts to be "vibrant", it begun to attract more residents to work and live in it. The city will grow and expand as a natural result of that. This continuous urban growth may lead to dangerous environmental impacts. Some cities during growth may consume valuable cultivated lands to provide spaces for accelerated demands of urban development projects. This leads to "Urban desertification". Moreover, future scenarios of these cities tell us that urban growth will continue and the city will expand consuming valuable resources. In this case, some important questions will arise; do we need this endless urban growth? Can we bear the consequences of this endless urban growth? Do we need to control this growth to keep the city vibrant? Or we just leave the city grow endlessly? This paper will try to address these questions on Alexandria of Egypt. Alexandria was a dream of Alexander III the Great. Alexander ordered that a city be designed and founded in his name at the mouth of river Nile, as trading and military Macedonian outpost, the first of many to come. He never lived to see it built, but Alexandria will become a major economic and cultural center in the Mediterranean world not only during the Macedonian rule in Egypt but centuries after. Alexandria witnessed a continuous urban growth from the beginning of the Mohammed Ali era (1805) up to the present time. In 1905, Alexandria's 370 thousand inhabitants lived in an area of about 4 km2 between the two harbors. Since that time the city has expanded rapidly, eastwards and westwards, beyond its medieval walls. It presently occupies a built-up area of about 300 km2 and has a ten-fold increase in population at 4 millions in 1996, and become 4.7 millions in 2014, with a density of 2,760 per km². The urban physical expansion and change were detected using Landsat satellite images of 1984 and 1993. The images were classified using a tailored classification scheme with accuracy of 93.82% and 95.27% for 1984 and 1993 images respectively. This high accuracy enabled detecting land use/cover changes with high confidence using a post-classification comparison method. One of the most important findings here is the loss of cultivated land in favour of urban expansion. If the current loss rates continued, 75% of green lands would be lost by year 2191. These hazardous rates call for an urban growth management policy that can preserve such valuable resources to achieve sustainable urban development. The starting point of any management programme will be based on the modelling of the future growth. Modelling techniques can help in defining the scenarios of urban growth in the future. In this study, the SLEUTH urban growth model was applied to predict future urban expansion in Alexandria until the year 2055. The application of this model in Alexandria of Egypt with its different environmental characteristics is the first application outside USA and Europe. The results revealed that future urban growth would continue in the edges of the current urban extent, which means the cultivated lands in the east and the southeast of the city will continue to lose more day by day from their area.To deal with such crisis, there is a serious need for a comprehensive urban growth management programme that can be based on the best practices in similar situations.

2 STUDY AREA

Alexandria is the chief port of Egypt and is located in the northern part of the country. Alexandria occupies a T-shaped peninsula and strip of land separating the Mediterranean from Lake Maryout. (Figure.1). Alexandria was founded in 331 BC by Alexander the Great and was the capital of Egypt for over 1000 years. Alexandria witnessed a continuous urban growth from the beginning of Mohammed Ali era (1805) up to the present time. In 1905, Alexandria's 370 thousand inhabitants lived in an area of about 4 km2 between the two harbours. Since that time the city has expanded rapidly, eastwards and westwards, beyond its medieval walls, Figure 2 shows the urban expansion of Alexandria . It presently occupies an area of about 300 km2 and has a ten-fold increase in population at 4 million, with a density exceeding 1,200 per km2. (Halim & Shouk, 2000) Population is projected to become 5.4 millions by 2015, figure 3 (United Nations, 1997). Because of this, Alexandria is the second largest urban governorate in Egypt. At an international level, the

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city was ranked 62 in 1996 and it is predicted to become rank 54 by 2015, (United Nations, 1997). This enormous urban growth requires precise detection with good management, prediction and planning.

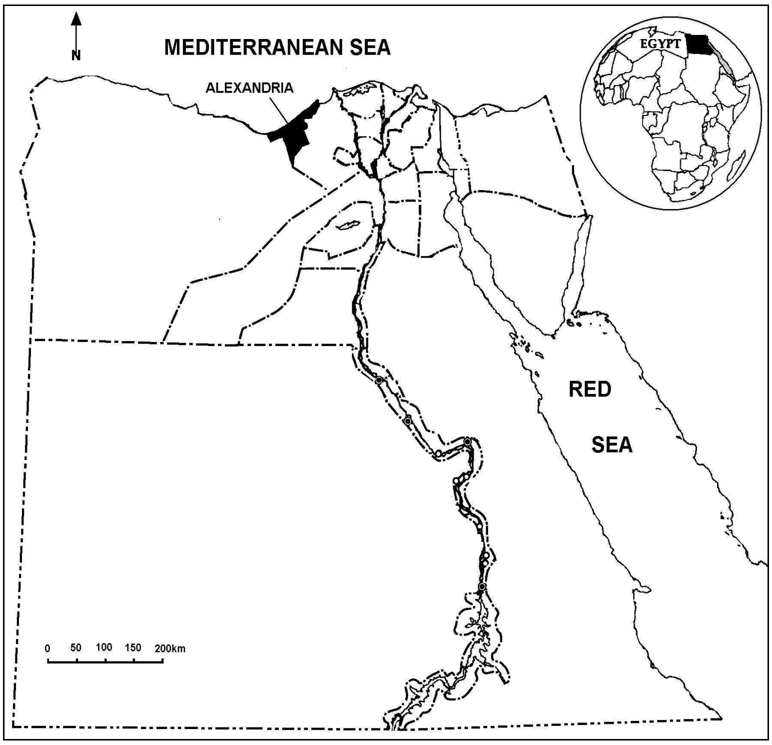

Fig. 1 Location map of the study area

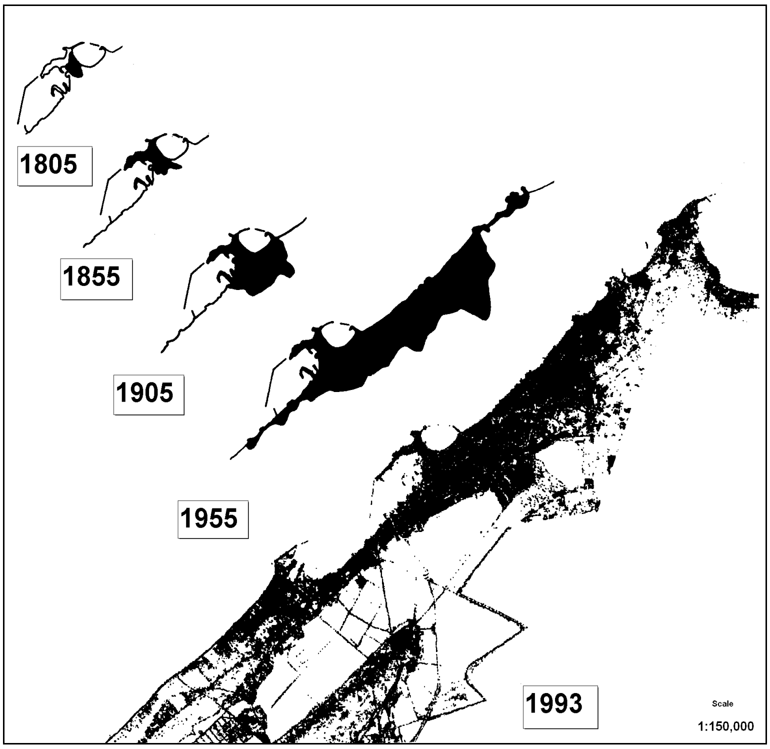

Fig.2 Physical Expansion of Alexandria during the 19th and 20th centuries

3 OBJECTIVES

The main objectives of this study are to detect changes and model urban growth in Alexandria through constructing an automated raster-based GIS to achieve the following sub objectives:

(1) Following the physical expansion of Alexandria from its establishment up to the contemporary stage and modelling growth stages.

(2) Production of contemporary satellite-based land use/land cover maps for the city.

(3) Mapping urban growth in Alexandria city, using multi-temporal change detection techniques

(4) Locating (defining the trends) and quantifying (size and rate) the changes of urban land use in the city at the specific period using classified satellite images.

(5) Defining the consequences of urban growth in Alexandria.

(6) Modelling urban growth in the city using the power of integrated spatial data (raster data / vector data / ancillary data) using the SLEUTH Model to simulate the future urban growth of the city.

(7) Managing future urban growth in Alexandria.

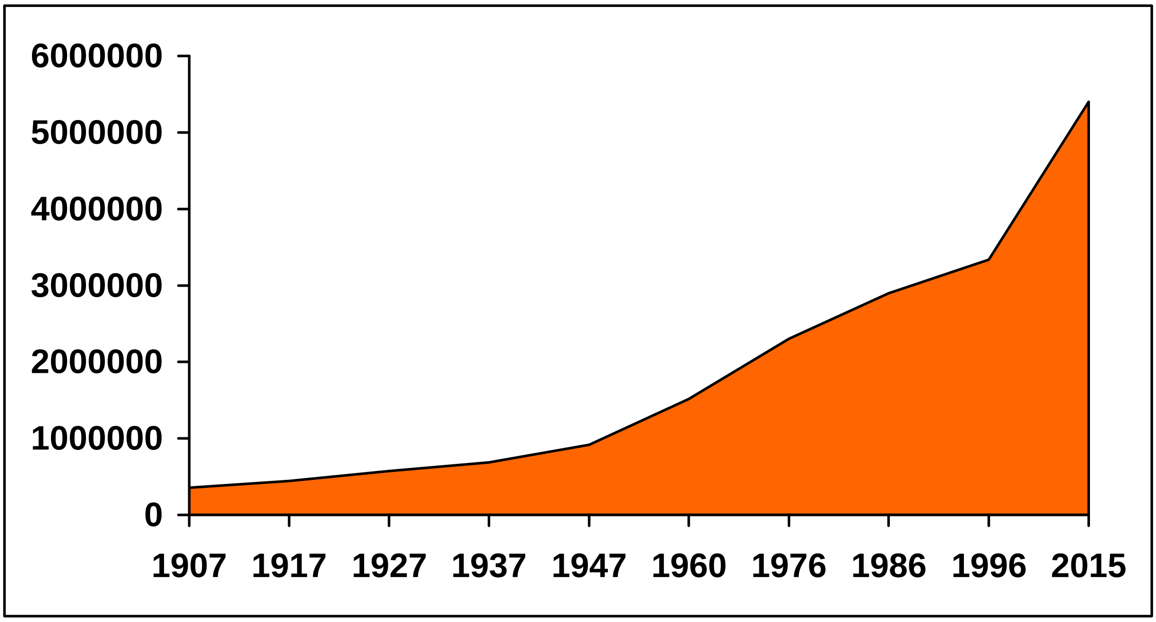

Fig.3 Alexandria population development

4 METHODOLOGY

4.1 Georeferencing

The satellite images used in this study were georeferenced with high accuracy providing a strong basis for further image analysis processes. The 1984 and 1993 images were rectified applying the first order transformation polynomial using between 39 and 43 GCPs from the reference maps of Alexandria of scale 1: 50,000. The transformation matrix was computed and tested many times achieving an acceptable total RMSE of 0.2566 pixel for the 1984 image and 0.2498 pixel for the 1993 image. Both images were resampled using the nearest neighbour method. Reference data source type has a great impact in decreasing RMSE of the rectified images and achieving high accuracy of land use/cover classification as the reference maps used in this study were produced from aerial photographs, which have their own high accuracy in presenting land features. This helped in achieving a very small RMSE and high accuracy classification as well.

4.2 Images Classification

Land use/land cover classification maps were produced with overall accuracy of 93.82% and 95.27% for 1984 and 1993 images correspondingly. Unsupervised classification using ISODATA clustering method was applied to perform classification. This study emphasizes the importance of special customisation of land use/ land cover schemes especially for developing countries studies as this research underlines the fact of non-existence of a universally applied classification scheme. In this context, a user-defined classification scheme has been customised to adapt with both data resolution and study area spatial and environmental characteristics. Figures (4 and 5) indicate the land use categories (classes) in Alexandria (1984, 1993).

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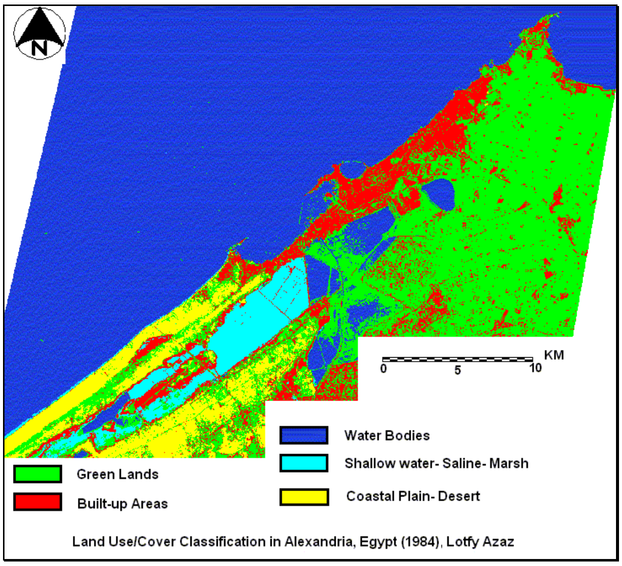

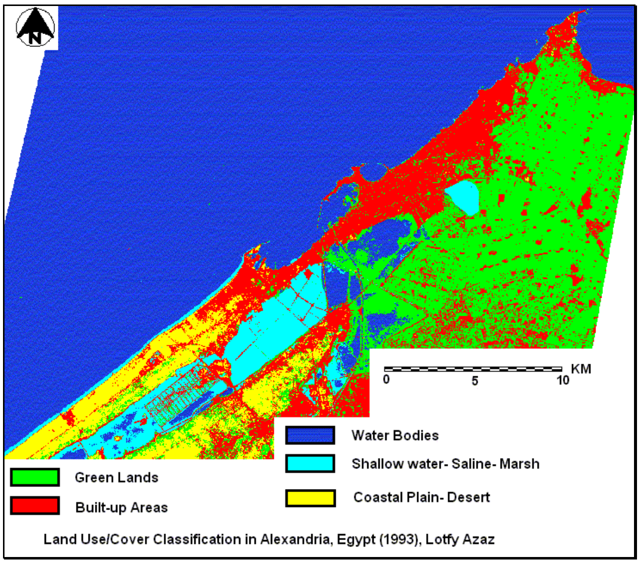

Fig. 4 Land use categories in Alexandria (1984), Fig. 5 Land use categories in Alexandria (1993)

4.3 Change Detection

In this study, two remotely sensed images (1984, 1993) were rectified, registered and classified into five classes. Land use/land cover change detection study reveals several changes in the period of study (1984-1993). These changes can be grouped into two divisions: spatial changes and quantitative changes. Spatial changes represent either emerging of new features or changing in the existing features. New features such as new Dekhila Port, Sidi Krir power station, fish farms, recreation villages, and lands reform projects appeared in the west. Maryout Lake was subject to some changes as some areas of the lake were dried to meet the accelerated demand for land; other parts of the lake have been used as Salina to produce salt. Indeed, all the above-mentioned features are results of urban development, but can be considered as indirect results. The direct results of urban development can be detected easily as new features in the eastern parts of the city consuming a significant part of the valuable agricultural lands. Moreover, the city centre area witnessed a little change of its existing features due to replacement and renewal factors. Quantitatively, green lands lost 23.79 % of its area for the built-up area with annual lose rate of 0.67%, which means the risk of losing about

75% of green land in the period between years 2096 and 2191. These are very optimistic projections if compared by other studies which estimated that ALL coastal agricultural lands in the northern of Egypt will be lost to urbanization and other activities by year 2061 (Salem et al., 1995). From a methodological point of view, Land use/land cover change analysis in Alexandria using post-classification comparison change detection method yielded high accuracy results especially if high-accuracy classified satellite images were used as inputs. The subtraction was done using Model Maker in Imagine 8.3 and the output (change map) was tested and proved using a Change Detection option in Imagine 8.4 and the result was the same. Figure (6) shows the change map for the area of study, summarized in Table (1).

Code	Was	Become	Code	was	Become
A	**Desert**	New Dekhila Port	**E**	**Lake**	Changes in Lake Maryout
B	**Desert**	Sidi Krir Power Station	**F**	**Desert**	Lands Reform Projects
C	**Lake**	Fish Farms	**G**	**Cultivated lands**	Urban expansion in the Eastern Areas
D	**Desert**	Western Coast	**H**	**Central Business District (C.B.D.)**	Central Business District (C.B.D.)

Table 1: Major Changes in Alexandria between 1984 and 1993

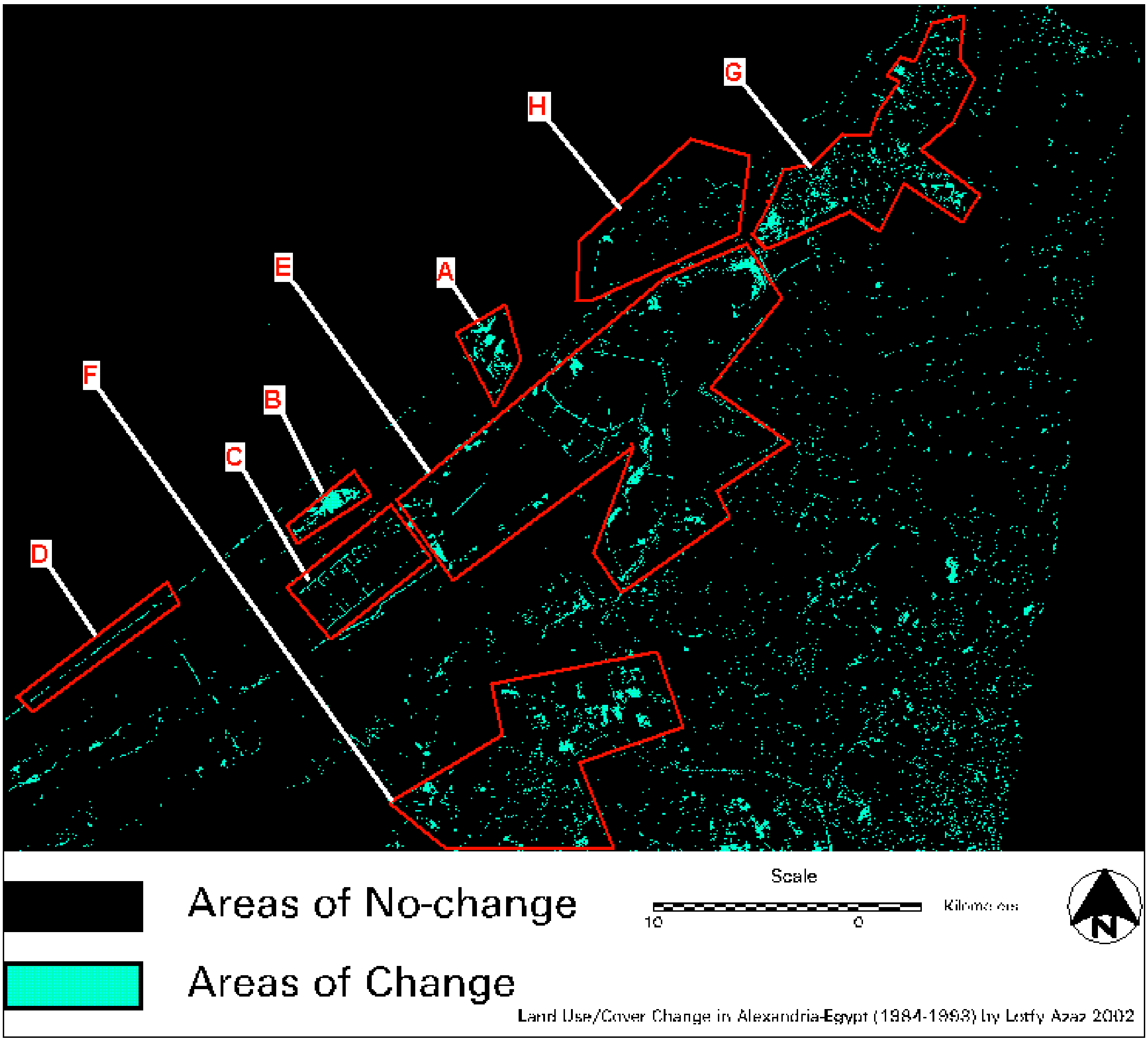

Fig. 6 Land use/land cover change in Alexandria (1984-1993)

4.4 Modelling Urban Growth

Modelling urban growth in Alexandria was done using SLEUTH model. The model was developed by Dr Keith C. Clarke of the Department of Geography, University of California, Santa Barbara. The name of the model (SLEUTH) was derived from the simple image input requirements of the model: Slope, Land cover, Exclusion, Urbanization, Transportation, and Hillshade (USGS 2000). The model is intended to simulate urban growth in order to aid in understanding how expanding urban areas consume their surrounding land, and the environmental impact this has on the local environment. This model simulates the transition from non-urban to urban land-use using a grid of cells (cellular automaton) each of whose land-use state is dependent upon local factors (e.g., roads, existing urban areas, topography), and temporal factors. Model inputs have been prepared for the area of study and the model was tested in its application phases.

The results of modelling urban growth using SLEUTH model emphasises that if the current physical urban expansion rates continued, it is expected that urban growth will persist in the edges of the current urban extent, Figure (7). This can be detected easily in the western, the southern, and the southeastern directions. Much development is expected to occur also around Al-Amrya area in the southwestern parts. The direction of urban growth to the southeastern parts means a serious threat to the cultivated lands, which already experience continuous loss.

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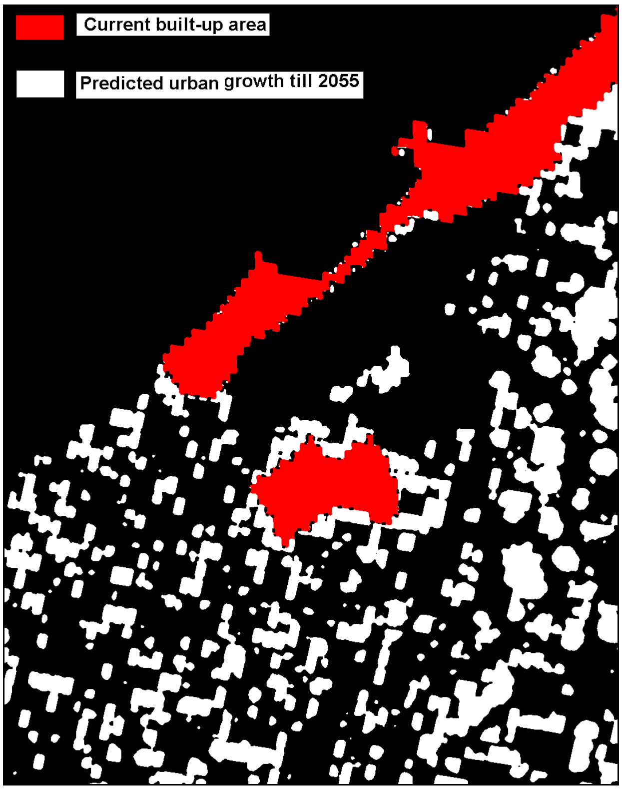

Fig. 7 Urban Growth in 2055 in all the area of study

5 RESULTS AND DISCUSSION

Table (2) shows the size and percentage of land use change in Alexandria area. Generally, the changes can be divided into two categories; (1) Increased change (positive) which includes built-up areas and Shallow water / saline and (2) Decreased change (negative) which includes green lands, desert and water bodies. The detailed change can be noticed in Table (3).

Class Name	**Size of Change (Hectare) (1984-1993)**	**Size of Change (Km²) (1984-1993)**	**Percentage of change (1984-1993)**	**Annual Change (Km²)**	**Annual Change (Percentage)**
Water Bodies	-2683.801	-26.838	-1.54	-2.982	-0.17
Shallow Water/S/M	2683.801	26.838	38.10	2.982	4.23
Green Lands	-6072.048	-60.72	-6.04	-6.747	-0.67
Built-up Areas	29240.729	292.407	56.74	32.489	6.30
Coastal Plain/ Desert	-23168.681	-231.687	-7.26	-25.74	-0.81

Table 2: The size of land use classes and the change in Alexandria area (1984-1993)

Water Bodies	**Shallow water**	**Green Lands**	**Built-up areas**	**Coastal Plain /Desert**	**Total**
Water Bodies	-2,683.801	0	0	0	-2,683.801
Shallow Water	2,683.801	0	0	0	2,683.801
Green Lands	0	0	-23,914.905	17,842.857	-6,072.048
Built-up Areas	0	0	23,914.905	5,325.824	29,240.729
Coastal Plain /Desert	0	0	-17,842.857	-5,325.824	-23,168.681
Total	2,683.801	-2,683.801	6,072.048	-29,240.729	23,168.681

Table 3: The gain and loss of Land Use/Land Cover categories in Alexandria Area (Hectare) between 1984 and 1993

The area of study witnessed a remarkable urban growth between 1984 and 1993. Two trajectories of urban expansion can be identified. The first is towards the eastern and southeastern parts of the area of study. This extension consumed the most valuable cultivated lands, which act as the hinterlands of Alexandria (the food basket of the city). If the current loss rates continue (0.67% annually) taking the year of 1984 as a base year, the green lands will face the risk of losing about 75% of its area through this artificial desertification by year 2191.

Nevertheless, if we use a more straightforward linear equation considering the annual loss (674.672 hectare), this means the green land will lose 75% of its area by year 2096. These projections of retaining some green lands are very optimistic. Another study estimated that all the coastal agricultural lands in northern Egypt will be lost to urbanization and other activities by the year 2061 (Salem et al., 1995). This indicates the need for strong policies to protect the valuable green lands from this serious continuous risk. These policies must direct urban growth trajectories to the lands that suit urban development. At the meantime, most of the urban expansion in the eastern parts is unplanned (Abdou-Azaz 1997) so there is a need also for planning solutions to this problem. Meanwhile, land reform projects should be continued to: a) compensate land lost to urban development, b) absorb part of the population increase, and c) provide employment and decrease unemployment rates as well especially for new graduates. The second trajectory is towards the western parts. This direction of expansion consumed only parts of the coastal dune series. Most of the expansion of built-up areas here is housing, but there are also other forms of built-up area such as storehouses and plants especially for petrochemicals and petroleum industries. Maryout Lake experienced different forms of changes. There is an urgent need to make appropriate decisions about the lake’s future. There is some change in the old city areas in the central and eastern parts of the study area; this change occurred as replacement and renewal processes.

6 CONCLUSION

This continuous urban growth led to dangerous environmental impacts in Alexandria. This growth consumes valuable cultivated lands to provide spaces for accelerated demands of urban development projects. This can be called “Urban desertification”. The future scenario Alexandria tells us that urban growth will continue and the city will expand consuming valuable resources. In this case, some important questions will arise; do we need this endless urban growth? Can we bear the consequences of this endless urban growth? Do we need to control this growth to keep the city vibrant? Or we just leave the city grow endlessly?

To deal with such critical questions, two approaches shall be adopted; the first approach requires legalization frame as a part of tough policies to direct urban growth of Alexandria towards suitable land for urban development, especially in the west and southwest of the city to protect the valuable agricultural lands. Moreover, to preserve the environmental resources of the city, especially the agricultural lands, this study suggests a greenbelt to be planned in the south of the city. This suggested greenbelt should be located before the agricultural lands leaving a reasonable buffer zone. GIS can help in placing this greenbelt and locating the buffer zone considering all geographical and environmental factors. Meanwhile, as most urban development in the eastern parts is unplanned, there is a need also for planning solutions for this problem as well. In addition, it is important not to allow vertical and horizontal expansion of the main built-up area as a response to continuous urban growth as this is considered as a short-sighted response as it will lead to easy access to the existing overextended services and utilities. The second approach suggests that future urban development process should create independent communities or even new cities. This approach would distinguish these communities from the core built-up area of the central city and reduce their dependence on its utilities and service systems (El-Shakhs 1997).

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