Impact of urbanization on agricultural land losses and climate change *Case study:* Gharbiah Governorate, Egypt

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Abstract: Urban expansion is one of the main problems that threaten the limited highly fertile land in the Nile Delta of Egypt. This study examines the impact of future urban expansion on local near-surface temperature for some regions in the Delta of Egypt using topographic map during 1985, SPOT5 satellite images 2,5m resolution during 2005 and satellite images from Google Earth during 2012 to monitor and measure the loss of agricultural land and urban expansion in the two districts of Gharbiah Governorate (Al Mahallah Al kubra and Samannoud). The future climate scenario (A2) was used to simulate the present (1985–2012) and future period (2030) climates of the regions. The future simulation incorporates the projected changes in the urban area of some regions of the Delta to account for the expected urban expansion. The rate of changes from 1985 to 2005 is higher in Al Mahallah Al kubra district in comparison with Samannoud district. Agricultural land decreased by 5.3% and the urban sprawl increased by 83.8% from 1985 to 2005 for the two districts. Per capita share of agricultural land was dwindled to around 0.17, 011, 010 and 0.07 feddan for the periods of 1985, 2005, 2012 and projection period of 2030. In spite of applying laws and regulations for curbing the encroachment on agricultural land, such policies have not succeeded in stopping urban encroachment on agricultural land. The analysis of the temperature changes revealed that future urbanization will strongly affect minimum temperature, whereas little impact was detected for maximum temperature. However, during summer and spring these differences will be particularly large and the increases could be double the increase due to global warming alone at 2030. Results indicated that the changes were mostly due to increased heat capacity of urban structures and reduced evaporation in the cities and their surroundings environment.
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Key words: Urban expansion; remote sensing; GIS; future climate scenario, near-surface temperature, climate change.

1. Introduction

The world's population is expected to increase to 8 billion by 2025 and 9 billion by 2050. For the first time, 52 percent of the world's population lives in urban areas. By 2030, six of out every ten people will live in cities; by 2050, this number will increase to roughly 70 percent of the global population (or 6 billion). By 2030, roughly 450 million people may be living in megacities (**UNDESA 2012**).

The growth of urban population has increasingly drawn the scientific community's attention to urban climate and the effects of urbanization at different scales (**Arnfield 2003**). The relative warmth of the urban areas with respect to the rural surroundings is undoubtedly the most prominent of these effects. The so-called urban heat island is primarily caused by the heat-storing structures that increase the heat capacity of the cities. Some studies have also identified the anthropogenic heat sources as an important contributor to this warming (**Kusaka and Kimura 2004**), especially in regions of intense energy consumption and low net radiation (**Lynn *et al.* 2009**).

The principal purpose was and still is to overcome Egypt's overwhelmingly unfavourable population to agricultural land ratio (**Springborg 1979**). The ever increasing population causes increasing pressure on areas already inhabited and caused a decrease in area per capita from 0.12 ha in 1950 to 0.06 ha in 1990 (**Suliman 1991**). Land transformation is one of the most important fields of human induced environmental transformation, with an extensive history dating back to antiquity (**Wolman *et al.* 1987**).

The integration of remote sensing and geographic information systems (GIS) has been widely applied and been recognized as a powerful and effective tool in detecting urban land use and land cover change. Despite the fact that the spatial resolution of recent climate change projections is getting close to resolving the urban climate (**Chin *et al.* 2005; Argüeso *et al.* 2012; Wagner *et al.* 2012**).

Some research organizations have put forward their indicators for measuring urban sprawl. Besides, many scholars focus on using indicators to measure urban sprawl by establishing multi-dimensional indicators by GIS analysis or descriptive statistical analysis (**Song and Knaap 2004, Frenkel 2005 and Schneider 2008**). Remote sensing and GIS can be separately or in combination for application in studies of urban sprawl. There are some researches on how to use remote sensing and GIS to monitor and measure urban sprawl, (**Jingnan *et al.* 2007, and Mahesh *et al.* 2008**).

The **IPCC's Fourth Assessment (2007)** noted the high adaptive capacity that is inherent within well-governed cities. In high-income nations, urban populations have become so accustomed to a web of institutions, infrastructure, services and regulations that protect them from extreme weather/floods that these are taken for granted. The objectives of this study are to investigate the urban sprawl and its impact on agricultural land, local and projection climate through integrating remote sensing and GIS.

2. Experimental design

2.1 Study area

The study area (Al Mahallah Al kubra and Samannoud districts) are located in Gharbiah Governorate on the north of Egypt. Its capital is Tanta, which is 90 km north of Cairo, and 120 km south east of Alexandria. The largest city in Gharbiah is Al-Mahalla El-Kubra. The coordinates of study area has been shown in Table (1). The total area of Gharbiah Governorate is 25,400 km², the majority of which are agricultural lands, while the total area of Al Mahallah Al kubra and Samannoud 455.66 and 154. km², respectively (**CAPMAS 2013**).

2.2 Data and methodology

Digital topographic map 1:50000 during 1985, SPOT5 satellite images 2,5m resolution during 2005 and satellite images from Google Earth during 2012 has been used to monitor and measure the land use/cover in the two districts of Gharbiah Governorate. Two land use/cover types are identified and used in this study, including: agricultural land losses and urban expansion. The urban expansion image was further overlaid with some geographic reference images to help analyze the patterns of urban expansion, including image of district boundary, major roads. These layers were built in a vector GIS environment and converted into a raster format.

2.3 Statistical analysis

Statistical modeling of build-up and population density data was represented as $y = f(x)$, where y is build-up expansion, x is population density. Correlations between (y) and (x) were studied to significantly determine ($0.0 \leq R2 \leq 1.0$). Linearized models form for analysis of build-up expansion (y) versus the population density (x) during the periods of 1985, 2005, 2012 and projection period of 2030.

Regression relationships between population density, agricultural land losses and build-up areas were analyzed by fitting regression equations to the data. Independent variables were the build-up parameters (e.g. area Km^2 and m^2) and dependent variable was the population density as the described method by **Argüeso *et al.* (2013)**.

2.4 Climate change to 2030

Climate change scenarios for locations were assessed according to future conditions derived from MAGICC/SCENGEN software of the university of East angle (UK). In this the study one GCM model (HadCM3) and one scenario of climate data were used A1 B. The principal of MAGICC/SCENGEN is allowing the user to explore the consequences of a medium range of future emissions scenarios **(Wigley *et al.*, 2000)**.

2.4 Assessment of the impacts

The study of the land use change effects under climate conditions was performed in stages. Firstly, the changes in monthly and annual maximum and minimum temperature were analyzed at seasonal timescales to determine the time of year when the impacts are largest. Despite the fact that this strategy does not allow the study of urbanization and GHG effects separately and thus it implicitly includes their non-linear interactions, it made possible the comparison of areas that are subjected to both climate change and urbanization with others that are affected only by climate change. The differences in their monthly temperature cycle give insight into the processes that control the temperature intensification as the method of **Arnfield (2003).**

A comprehensive description of the urbanization effect on future climate was sought in this study.

Table 1: The coordinates of study area

District/region	Longitude E	Longitude N
Al- Mahalla Al Kubra	31° 05° 38.70°	30 ° 59° 16.60°
Samannoud	31° 15° 39.20°	31 ° 0° 14.40°
Gharbiah Governorate	31° 15° 39.20°	30 ° 59° 16.60°

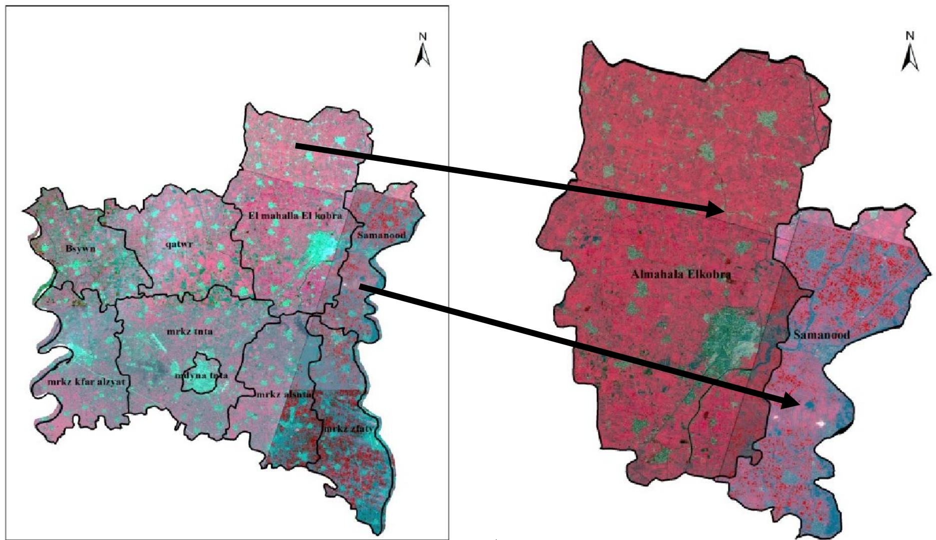

Figure1: Map of the study area

3. Results and Discussion

3.1 Urbanization changes

Result of digital topographic map, SPOT5 satellite images and the satellite images from Google Earth interpretation shows that during 27 years, from 1985 to 2012, agricultural land was decreased by 32,18 (km^2), the change percentage at Al- Mahalla Al Kubra district was -8 % and built - up land was increased by 32.81(km^2) the change percentage was 126%. While the agricultural land was decrease by 11.64 (km^2), with change percentage -9% and built-up land was increased by 11.64 (Km^2) the change percentage was 152%. Results revealed, there were contrast losses in agricultural land converted to built-up land in both districts.

Between 1985 and 2005 the agricultural land at Al- Mahalla Al Kubra district was decreased from 397.57 to 377.33 (km^2), the change percentage was -5%, and built-up land was increased from 25.64 to 50.25 (km^2), the change percentage was 96%. Whereas, for Samannoud district in agricultural land decreased from 136.81 to 131.34 (km^2), the change percentage was -4% and built-up land was increased from 7.65 to 13.12 (km^2) the change percentage was 72%.

Between 2005 and 2012, the agricultural land at Al- Mahalla Al Kubra district was decreased from 377.33 to 365.37 (km^2), the change percentage was -3%, and built-up land was increased from 50.25 to 57.82 (km^2), the change percentage was 15%. Whereas, for Samannoud district in agricultural land decreased from 131.34 to 125.17 (km^2), the change percentage was -5% and built-up land was increased from 13.12 to 19.29 (km^2) the change percentage was 47%.

The total agricultural land in Al Mahallah Al kubra and Samannoud districts during the period from 1985 to 2005 were decreased from 534.38 to 508.67 (km^2), the change percentage was 5% and the total built-up land was increased from 33.29 to 63.37 (km^2) the change percentage was 90%. Although, the total agricultural land in Al Mahallah Al kubra and Samannoud districts between 2005 and 2012, decreased from 508.67 to 490.59 (km^2), the change percentage was -4% and the total built-up land was increased from 63.37 to 77.11 (km^2), the percentage change was 22%. The total agricultural land in Al Mahallah Al kubra and Samannoud districts during the period from 1985 to 2012 were decreased from 534.38 to 490.59 (km^2), the change percentage was -8% and the total built-up land was increased from 33.29 to 77.11 (km^2) the change percentage was 132% (see Table 2). Results of urban expansion and loss of agricultural land in Al Mahallah Al kubra and Samannoud districts during three different years of1985, 2005 and 2012 from remotely sensed data and GIS to analyze has been shown in Figure (2).

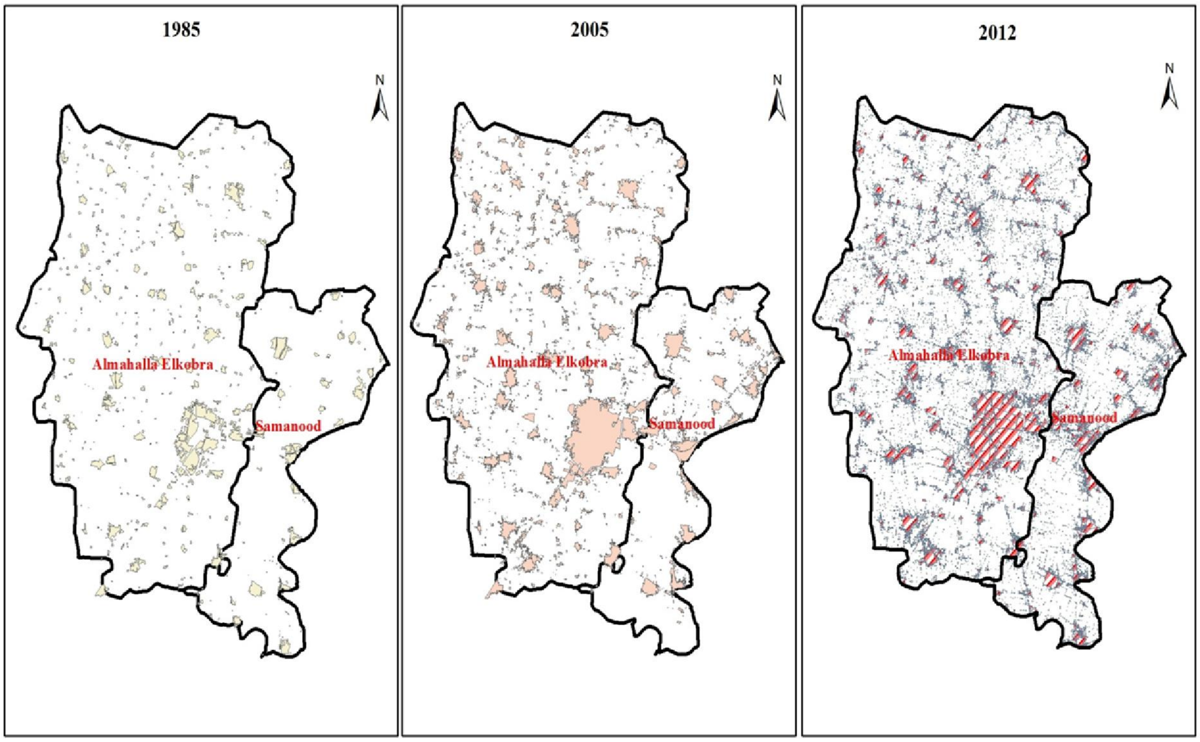

Figure 2: Results of urban expansion and loss of agricultural land in Al Mahallah Al kubra and Samannoud districts during three different years 1985, 2005 and 2012 from remotely sensed data and GIS to analyze.

Table2: The Built-up and agricultural land in Al Mahallah Al kubra and Samannoud districts during the study period

Districts	Land use/cover (km^2)	1985	2005	2012	Change (%) (1985-2005)	Change (%) (2005-2012)	Change (%) (1985-2012)
Al Mahallah Al kubra	Agricultural land	397.57	377.33	365.39	-5	-3	-0.08
	Built-up land	25.64	50.25	57.82	96	15	126
Samannoud	Agricultural land	136.81	131.34	-	-4	-5	-9
	Built-up land	7.65	13.12	19.29	72	47	152
Total Agricultural land (km^2)		534.38	508.67	490.56	-5	-4	-8
Total Built-up land (km^2)		33.29	63.37	77.11	90	22	132

3.1.1 Per capita area changes

Per capita share of agricultural land of Gharbiah Governorate was dwindled to around 0.17, 0.11, 0.10 and 0.07 feddan for the periods of 1985, 2005, 2012 and projection period of 2030 (Table 3 and Figure 3). In spite of applying laws and regulations for curbing the encroachment on agricultural land, such policies have not succeeded in stopping urban encroachment on agricultural land. Lost agricultural land in Egypt has been estimated at around 20,000 feddan per annum (**SADS 2010**). In spite of their limited effect, applied procedures have become a pivotal concern of agricultural directorates at the governorate level, thus reducing the institutional capabilities of these directorates to untangle the constraint. Establishing an integrated framework to achieve balance between rural population urbanization requirements, due to the fast population increase of rural inhabitants, and protecting agricultural land. (**SADS 2010**).

Table 3: Population density, built-up area (km^2), agricultural lands (km^2) and per capita area (m^2) in 1985, 2005, 2012 and projection 2030 of Al Mahallah Al Kubra, Samannoud districts and Al-Gharbiah Governorate, Egypt.

District/region	Item	1985	2005	2012	2030
Al Mahallah Al kubra	Population	306509	431958	477950	622426
	Build-up (km^2)	25.64	50.25	57.82	75.298
Samannoud	Population	198582	298166	329913	429640
	Build-up (km^2)	7.65	13.12	19.29	25.121
Gharbiah	Population	2572456	3625319	4011320	5332120
	Build-up (km^2)	121.05	237.24	272.98	362.86
	Agric. Lands (km^2)	1822.22	1706.03	1670.40	1580.52
Area per capita (m^2)* in Gharbiah	**Build-up (m^2)**	**47.06**	**65.44**	**68.05**	**68.05**
	Agric. lands (m^2)	**708.36**	**470.59**	**416.42**	**296.41**
	Agric. lands (feddan)	**0.17**	**0.11**	**0.10**	**0.07**

Source: CAPMAS (Central Agency for Public Mobilization and Statistics), Egypt.
Note: entries marked with an asterisk (*) is compiled and computed from the statistical table.

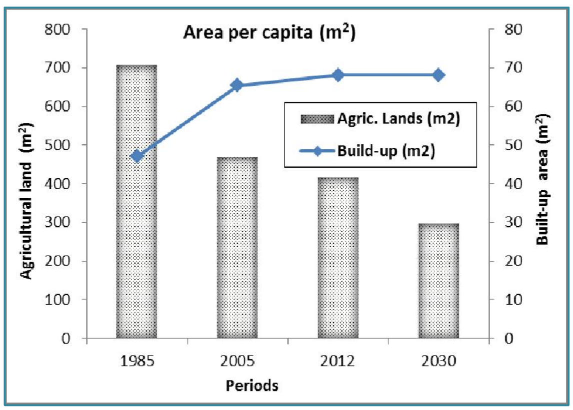

Figure 3: Results of per capita area of urban expansion and loss of agricultural land in **Gharbiah Governorate** during three different years 1985, 2005 and 2012 from remotely sensed data and GIS analysis.

3.1.2 Regression analysis of urbanization expansion

Linearized models form for analysis of build-up expansion (y) versus the population density (x) for both districts (Al Mahallah Al kubra and Samannoud) during the periods of 1985, 2005, 2012 and projection period of 2030. The obtained results from regression indicated that, the statistics relationships between build-up expansion and population density of two districts is a polynomial model. The polynomial models have been used to describe growth processes or analogous processes in many disciplines (**Argüeso *et al.* 2013**).

The following model presented in Figure (4) is the polynomial equations as a result of regression analysis between build-up expansion, population density and agricultural land of the region over time periods (1985, 2005, 2012 and projection 2030).

$y = -2E\text{-}10x^2 + 0.0004x - 62.287, R^2 = 0.9989$ ...(1)

$y = 1E\text{-}11x^2 + 7E\text{-}05x - 6.9211, R^2 = 0.9594$.... (2)

$y = -1E\text{-}11x^2 + 0.0002x - 294.07, R^2 = 0.968$ ....(3)

$y = -1E\text{-}11x2 + 0.0002x - 294.07, R^2 = 0.978$ ... (4)

Equations (1), (2) and (3) are the regression models for Al Mahallah Al kubra, Samannoud districts and Gharbiah, respectively. Statistical modeling of build-up and population density data was represented as y = f (x), where y is build-up expansion, x is population density. Equation (4) is regression model for per capita area (m2) between built-up (x) and agricultural land (y). Correlations between (y) and (x) were studied to significantly determine ($0.95 \le R2 \le 0.99$) which is very high correlated relationships.

3.2 Temperature changes

Actual and seasonal changes of monthly maximum temperature are collected and projected (Fig. 5a). Nonetheless, indicates that slightly larger changes are increased during summer months in Gharbiah. Indeed, it is during 2030 and over this area that the largest Tmax increases are projected, which could reach up to 8°C. Although, there is signal of land-use change effects on maximum temperature.

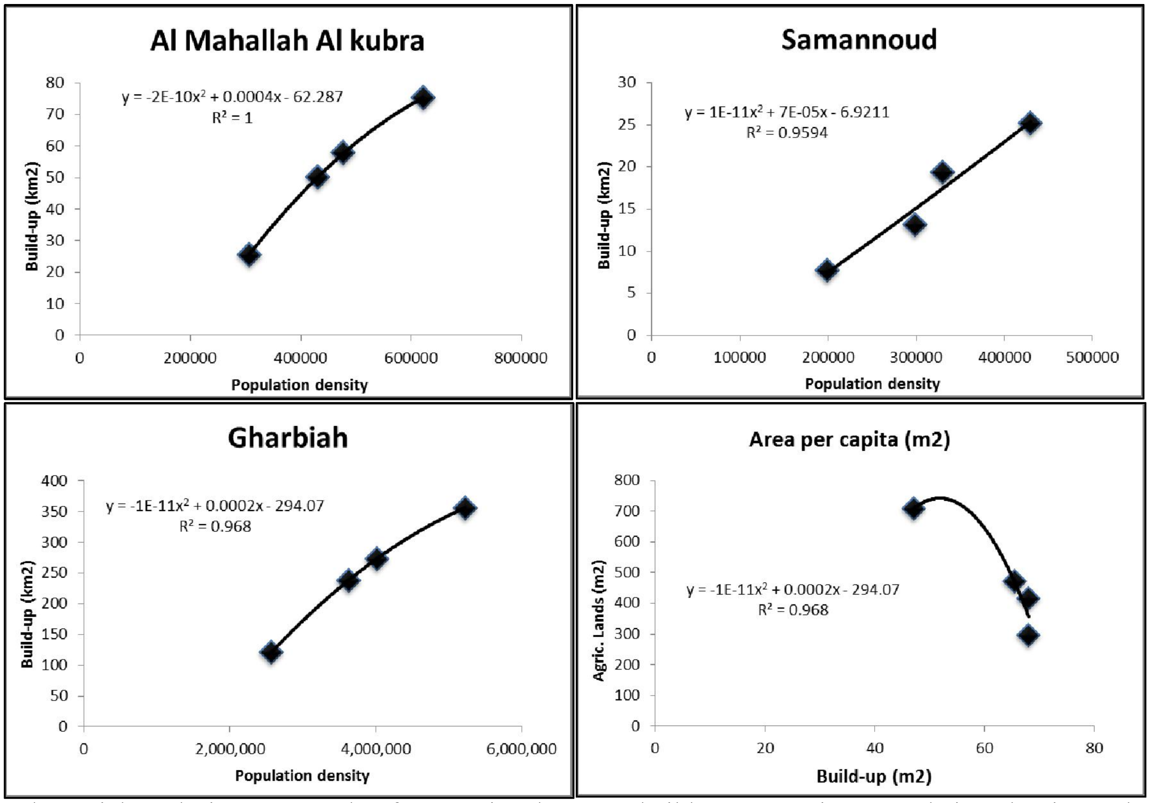

Figure 4: Polynomial analysis as a result of regression between build-up expansion, population density and agricultural land of the districts/region over time periods (1985, 2005, 2012 and projection period of 2030).

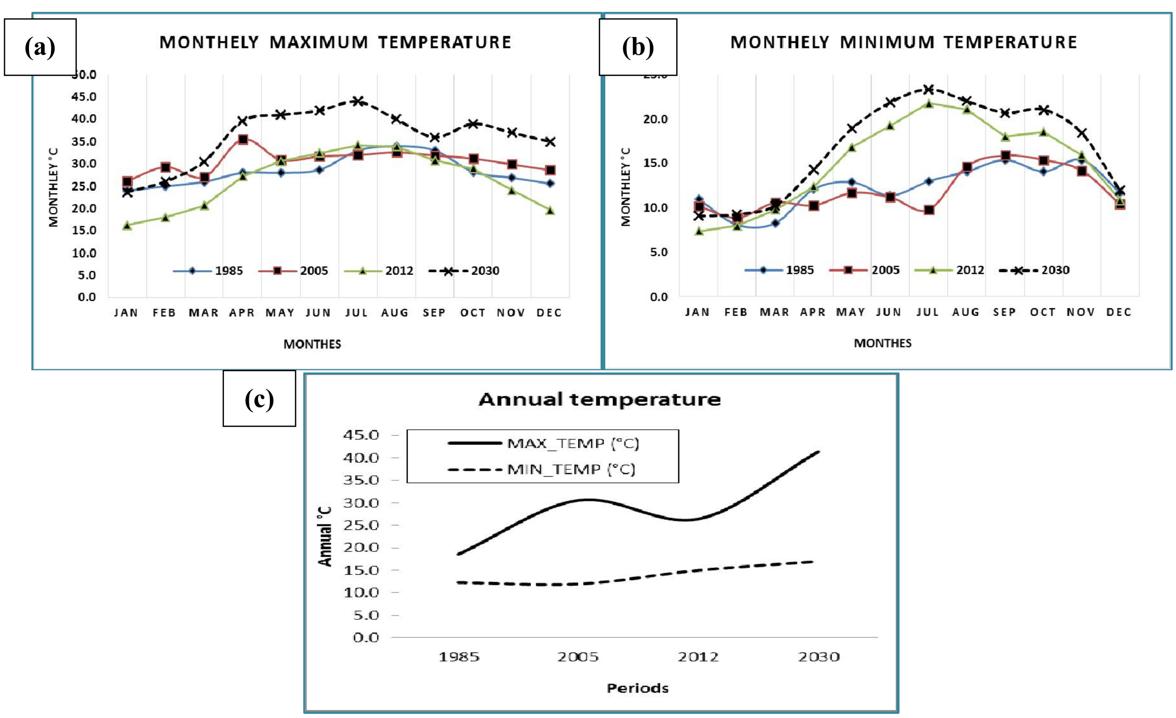

Figure 5: Seasonal means of monthly maximum and minimum temperatures (a-b), and annual maximum and minimum temperatures (c) for periods of 1985, 2005, 2012 and projection 2030 for Al-Gharbiah governorate.

The most remarkable feature of Tmin seasonal changes is indeed the evident footprint of the newly urbanized areas (Fig. 5b). The areas subjected to future land-use changes are clearly identifiable (see Fig. 5c) in the annual mean temperature seasonal changes because they are projected to experience substantially larger increases. The changes in minimum temperature are relatively moderate during winter (+4.5 °C) and particularly marked during summer and autumn, when they are projected to reach up to 10 °C around the new urban areas. The same results generally found to be best displayed during the summer months (**Wilby 2008 and Argüeso *et al.,* 2013**), except for high-latitude cities where radiation has a very strong seasonal cycle and the heat from urbanization is stronger during winter (**Hinkel *et al.* 2003**). However, some authors detected either a more intense heat from urbanization during cold months (**Kim and Baik 2002**). Despite the seasonal differences, the land use change footprint is clearly noticeable in all seasons.

The contrasting response between Tmax and Tmin seasonal changes is in agreement with previous studies that characterized the heat from urbanization for present climate and found greater heat intensity during night (**Arnfield 2003**). This is explained by the higher heat capacity of urban structures that stores more energy during daytime and slowly releases it during nighttime, also plays an important role because it contributes to delaying the loss of heat through multiple reflections and the trapping of near-surface air.

Most cities in Africa, Asia and Latin America and the Caribbean will experience more heat waves. Even small increases in average temperature can result in large shifts in the frequency of extremes (**Kovats and Aktar 2008**). Many cities will face more problems with certain air pollutants as concentrations of air pollutants change in response to climate change because a portion of their formation depends, in part, on temperature and humidity. In Andhra Pradesh, India, a heat wave killed more than 1,000 people – mostly labours working outside in high temperatures in smaller urban settlements (**Revi, 2008**).

3.2.1 Regression analysis of change temperature

Linearized models form for analysis of annual temperatures (y) versus the agricultural land losses (x) for the studies region during the periods of 1985, 2005, 2012 and projection period of 2030. The obtained results from regression indicated that, the statistics relationships between annual maximum and minimum temperatures versus the agricultural land losses are a power and polynomial model, respectively.

The following model presented in Figure (6 a,b) is the power and polynomial equations as a result of regression analysis:

$y = 6062.6x^{-0.88}$, $R^2 = 0.901$…………………… (1)

$y = 5E\text{-}05x2 - 0.0662x + 32.126$, $R^2 = 0.8724$… (2)

Equations (1) and (2) are the statistics relationships between annual maximum and minimum temperatures versus the agricultural land losses, respectively for Gharbiah Governorate. Correlations between (y) and (x) were studied to significantly determine ($0.87 \leq R^2 \leq 0.90$) which is high to very high correlated relationships.

4. Conclusion

This study demonstrates the use of remote sensing and GIS to analyze the urban expansion and loss of agricultural land and detect changes of urban land use/ land cover through different periods. Results revealed a notable increase in urban land and decrease in agricultural land between 1985 and 2012. New urban development occurs mainly on vegetation and agricultural land. GIS and remote sensing can help a lot in monitoring urban sprawl compared to conventional techniques. The main objective of this paper was to ascertain the combined effect of urbanization and climate change on near-surface temperature as simulated by linear model. Projected urban expansion was incorporated in the future climate simulation and a comparison of temperature changes between unaltered and urbanized regions was performed to determine the magnitude of the urbanization impact with respect to the climate change signal. Urbanization has an important effect on almost every variable that was analyzed. In particular, the projected land use changes were found to have a strong effect on future minimum and maximum temperatures that adds to the warming caused by GHGs. Indeed, minimum temperature is systematically projected to increase more in newly urbanized areas. The changes are noticeable all through the year, but they are especially marked during summer and spring, when minimum temperature increases over these areas could actually double the increase due to global warming alone by 2030.

The analysis of the annual-averaged temperature cycle shows that the magnitude of the urbanization impact on temperature is locally comparable to the climate change signal.

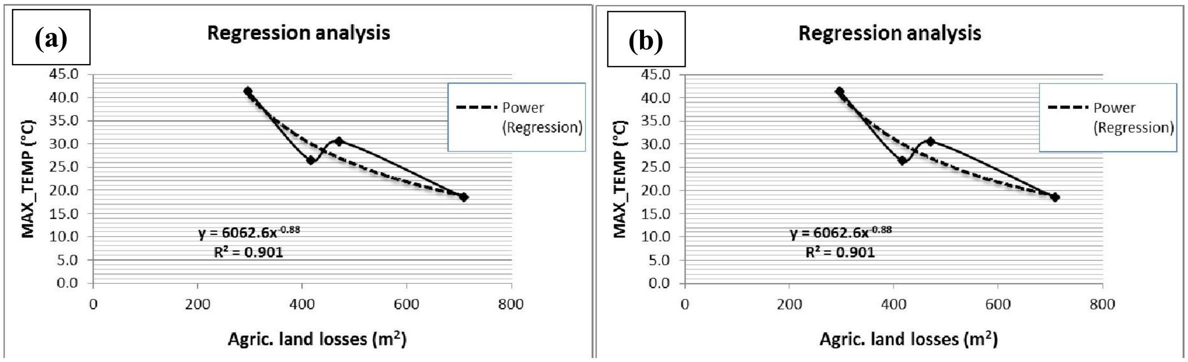

Figure 6: Regression analysis between agricultural land losses and annual maximum temperature (a) and annual minimum temperature (b) of the Gharbiah region over time periods (1985, 2005, 2012 and projection period of 2030).

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