The impact of climate change on urbanization: A case study on two Egyptian Governorates (Dakahlia and Ismailia)

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Urbanization is formed through the development of cities, making them a centre for transport, trade and information flow. A close link between urbanization and economic growth appears by attracting residents to cities that provide diverse opportunities for education and work, especially in the sectors of Industry and services. Urbanization can be planned or spontaneous. Each has its determinants; planned urbanization might have disparate economic, social, and climate determinants. However, if urbanization is unplanned, its main determinants are internal migration and natural increase. Climate change, including the scarcity of precipitations, heat stress, and moisture level change, might harm agriculture and push agricultural labour to migrate to urban areas.

Additionally, studying the impact of climate change is scarce at the level of the Egyptian Governorates. Our study aims to estimate the effect of heat stress, moisture level, and precipitation on the urbanization degree (percentage of the urban population). The analysis will be focused on two Egyptian governorates (Dakahlia and Ismailia) from 2000 to 2020. The chosen Governorates include urban and rural areas. The analysis will draw on the compiled data on climate conditions from the Annual Bulletin of Environment Statistics, CAPMAS. The data on the urbanization degree are pooled from the Statistical Year Book, CAPMAS. We will use Autoregressive Distributed Lag Model (ARDL) to estimate the plausible impact of climate change in the two governorates under study. The results show that maximum temperature and humidity significantly affect urbanization in Dakahlia. However, the effect of the lagged values of urbanization is the only significant variable in the Ismailia model. For future research, the study will be extended to cover the remaining Egyptian Governorates, including rural and urban areas.

Keywords: Climate change, Heat stress, Temperature, Precipitation, Urbanization

Introduction

Climate change is the discourse of researchers nowadays, and its causes and implications should be investigated (Henderson et al., 2014; Latief et al., 2022; Li et al., 2022). The last decade encountered apparent changes in temperature. Moreover, climate change can be manifested through indicators such as mean temperatures, sea levels, precipitation, and droughts (Dabaieh et al., 2022). Additionally, the poor urban population are most at risk from increased climate disasters, lack of services, poor infrastructure, and poor quality of life (Satterthwaite, 2007).

Although the researchers analyzed the effect of urbanization on climate change, the literature did not fully address the impact of climate change on urbanization. However, recently some researchers shed light on the plausible effect of environmental changes on urbanization. The uncontrollable increase in harmful gases emission might suppress the urbanization process. The pollution resulting from urbanization in the last decades yielded the exacerbation of respiratory diseases and the deterioration of the infrastructure in urban cities (Wu et al., 2020). Nevertheless, the urban population increase as a result of the economic development was also a two sworded arrow. The economic development without capturing the harmful impact of development and human activities on the environment led to the elevation in heat stress. In addition, this change in the average temperature might have

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an adverse impact on urbanization. Thus, the urban population might return to the countryside to avoid climate change in cities (Chai, Ma, Yang, Lu, & Chang, 2022).

On the other way round, some studies found that the implications of heat stress might push the rural population to migrate to urban areas. They may suffer more from climate change due to their vulnerability, poor living conditions, and inability to adapt to the new environmnental conditions, and eventually increase urbanization in the long run (Helbling & Meierrieks, 2022). In their systematic review, Murshed & Yusuf Saadat (2018) found that urbanization primarily impacts climate change in the long run in Bangladesh. On the other hand, the results of this study also indicated that renewable energy consumption could decrease CO_2 and CH_4 emissions.

Because of the contradicted results of the literature and the scarcity of studies that estimate climate change's impact on urbanization, this paper analyzes the implications of climate change on Egypt's urbanization, primarily in two Egyptian Governorates, Dakahlia and Ismailia.

Data and Methods

The analysis will be focused on two Egyptian governorates (Dakahlia and Ismailia) from 2000 to 2020. The chosen Governotaes include urban and rural areas. The analysis will draw on the compiled data on climate conditions from the Annual Bulletin of Environment Statistics, CAPMAS. The data on the urbanization degree are pooled from the Statistical Yearbook, CAPMAS. We will use time series regression to estimate the plausible impact of climate change in the two governorates under study. The analysis aims to estimate the relationship between urbanization and climate variables. We used four climate variables as independent variables: maximum temperature, minimum temperature, humidity and precipitation. Urbanization was only available yearly, that's why we computed the yearly average estimates of climate variables.

We adopted the ARDL (Autoregressive distributed lag) regression model to estimate the effect of climate change on urbanization in the two Governorates. The model equation can be written as follows:

$$\text{Urbanization}_t = \delta_0 + \sum_{i=1}^{P} \delta_i \, Urbanization_{t-i} + \sum_{j=1}^{k} \beta_{1j} \text{Max\_temp}_{t-j} + \sum_{j=1}^{k} \beta_{2j} \text{Min\_temp}_{t-j} + \sum_{j=1}^{k} \beta_{3j} Precipitation + \sum_{j=1}^{k} \beta_{4j} \text{Humidity}_{t-j} + \varepsilon_t. \quad (1)$$

Where y_t is the urbanization degree at time t (proportion of urban population), Max_temp_t and Min_temp_t are the maximum and minimum temperature at time t (the average temperature per year in C), Precipitation_t is the average rain fall per year in (mm), Humidity_t is the humidity level at time t (proportion), and ε_t is the error, where (t=1,……,T), (i=1,….,p), and (j=0,….,k).

The summary statistics of urbanization and climate characteristics of the two governorates through the 21 years under study are presented in Table 1. The mean maximum and maximum temperatures are higher in Ismailia (29.9, 16.6) than in Dakahlia (28.5, 15.2). Humidity level and precipitation are higher in Dakahlia (0.65, 4.02) than in Ismailia (0.53, 0.41) because Dakahlia has more rural areas that might increase the humidity level. The rural structure of Dakahlia is reflected by a lower mean urbanization degree than Ismailia Governorate (0.28, 0.46, respectively).

Table1. Descriptive statistics for the data for the 2000-2020 in Dakahlia and Ismailia Governorates.

Dakahlia							
Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
max_temp	21	28.56	2.31	27.175	27.575	28.233	36.6
Min_temp	21	15.286	2.521	13.696	13.85	15.417	24.6
Humid	21	0.652	0.087	0.339	0.637	0.682	0.788
Precipitation	21	4.012	3.233	0.609	1.742	5.778	14.6
Urbanization	21	0.284	0.006	0.279	0.28	0.283	0.3
Ismalilia							
Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
max_temp	21	29.913	2.727	28.329	28.417	29.6	39.4
Min_temp	21	16.693	2.691	14.932	15.058	16.75	25.2
Humid	21	0.539	0.182	0	0.565	0.605	0.694
Precipitation	21	2.411	1.281	0.3	1.567	3.027	5.1
Urbanization	21	0.469	0.023	0.446	0.451	0.499	0.505

The first step in our empirical analysis is taking a glance at the urbanization data. Figure 1 depicts the evolution of urbanization through the years under study in the two governorates. We have chosen two Governorates with different patterns to check the climate effect in both, avoiding bias. Additionally, we imputed the first four values in the series on urbanization. The urban population in Dakahlia increased from 28% to 30% through the 21 years under study. However, in Ismailia Governorate, the urban population decreased from 50% to around 45% in 2020.

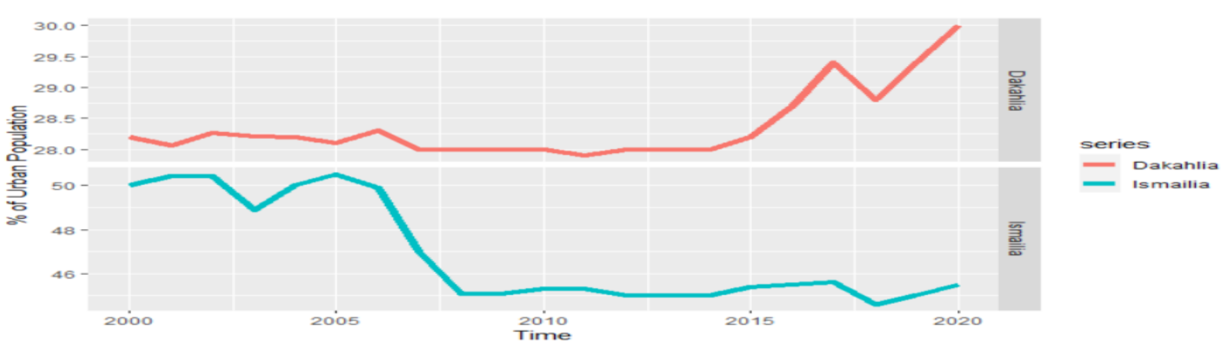

Figure1. Percentage of urban population in Dakahlia and Ismailia over the 20 years under study.

We started our analysis by checking the stationarity of the data and the integration order. Hence, in Table 1, we conducted the ADF unit root test (Dickey & Fuller, 1979). The results of the test differ in the two Governorates. In Dakahlia, The three of the series are I(1), and the rest are I(0); the mixed structure of the series recommends using ARDL model (Pesaran, Shin, & Smith, 2001). Additionally, in Ismailia, all of the series are integrated of order I(1) which implies the possibility of cointegration between variables. Thus, we performed the ARDL model, which is the most appropriate to detect the short-run and long-run relationships between the dependent and the independent variables.

Table 2． Augmented Dickey–Fuller (ADF) test results in the two Governorates.

Variables	Integration Order (Dakahlia)	P-Value	Integration Order (Ismailia)	P-Value
Urbanization	I(1)	0.9761	I(1)	0.8636
Maximum_Temprature	I(1)	0.2841	I(1)	0.5344
Minimum_Temprature	I(1)	0.1925	I(1)	0.6017
Humidity	I(0)	0.0239	I(1)	0.6924
Precipitation	I(0)	0.04783	I(1)	0.0994

To estimate the effect of the climate variables on urbanization in the two Governorates, we conducted the ARDL model using Equation (1). First, before estimating the model, we needed to choose the optimal lag for each variable according to the Akaike Information Criteria (AIC). In the case of our study, we have a short series, so the maximum order was 3, and the best lags are ARDL (2,3,2,2) in Dakahlia and ARDL (1,0,0,0) in Ismailia. Before proceeding, the diagnostics tests of the unrestricted ARDL model appear at the end of Tables 3 and 4, indicating that the residuals are normally distributed, independent, and homoscedastic. The F bound test indicates that there is a cointegration, and we need to capture the long-run effect in the model in Dakahlia.

All the variables were transformed to log; the minimum temperature was deleted because of multicollinearity with maximum temperature. Table 3 presents the short-run effect of the variables and the error component. The results state that the differenced lags of humidity appear to be positive and significant until the second lag in Dakahlia model (P-value <0.001), and the maximum temperature is significant and positive at time t (P-Value <0.05). Table 3 shows that the error component is significant, negative and between zero and one, which means that the urbanization is out of equilibrium, and the discrepancy between the short-run and the long-run equilibrium is modified using the lags of the independent variables by 67% each year (P-Value<0.001), but the rest of the variables are insignificant. The model is significant, F-statistics indicates the joint contribution of the explanatory variables in explaining the urbanization, and the R-Squared is 95%.

Table 3. The results of ARDL (ECM-Representation-Short run model) in Dakahlia Governorate.

	d(Urbanization)			
Predictors	*Estimates*	*CI*	*Statistic*	*p*
(Intercept)	-0.918374 ***	-1.260022 – -0.576725	-6.198694	0.000260
d(L(Urbanization, 1))	-0.430094	-0.926064 – 0.065876	-1.999715	0.080552
d(Humid)	-0.063814 ***	-0.087040 – -0.040588	-6.335778	0.000224
d(L(Humid, 1))	0.082569 ***	0.056067 – 0.109071	7.184546	0.000094
d(L(Humid, 2))	0.067165 ***	0.039794 – 0.094535	5.658728	0.000477
d(max temp)	0.029877 *	0.000945 – 0.058809	2.381310	0.044455
d(L(max temp, 1))	0.005765	-0.025208 – 0.036739	0.429237	0.679077
d(Precipitation)	-0.002368	-0.006195 – 0.001459	-1.426694	0.191507
d(L(Precipitation, 1))	0.002458	-0.001490 – 0.006406	1.435667	0.189019
ect	-0.672067 ***	-0.921385 – -0.422749	-6.216110	0.000255
	F-statistic: 16.89		p-value: 0.0002725	
R^2 / R^2 adjusted	0.950 / 0.894			

** p<0.05 ** p<0.01 *** p<0.001*

Breusch-Godfrey test for serial correlation of order up to 1

LM test = 1.8222, df1 = 1, df2 = 3, p-value = 0.2699

Breusch-Pagan Test for the homoskedasticity of residuals:

BP = 6.5836, df = 13, p-value = 0.9223

Ramsey's RESET Test for model specification:
RESET = 0.13843, df1 = 2, df2 = 6, p-value = 0.8734

Bounds F-test (Wald) for no cointegration
F = 6.0375, p-value = 0.0478

Shapiro-Normality test
W = 0.95434, p-value = 0.4971

Table 4 states the effect of climate change variables on urbanization. The results show that the only significant variable is the first lag of urbanization (P-Value<0.001). The model is significant, and the R-Squared is 84%. The model diagnostics reveal the homoskedasticity, normality, and independence of errors. Additionally, the model is stable according to the Ramsey test, but unfortunately, the F bound test doesn't show a significant cointegration. Accordingly, we didn't estimate the error correction term that captures the difference between the long-term and the short-term effect.

Table 4. The results of ARDL in Ismailia Governorate.

	Urbanization			
Predictors	*Estimates*	*CI*	*Statistic*	*p*
(Intercept)	-0.175467	-0.901608 – 0.550674	-0.515051	0.614024
L(Urbanization, 1)	0.926745 ***	0.643759 – 1.209731	6.980237	0.000004
Humid	-0.063028	-0.328412 – 0.202356	-0.506214	0.620065
max temp	0.024829	-0.185310 – 0.234969	0.251844	0.804580
Precipitation	-0.002529	-0.018063 – 0.013006	-0.346968	0.733435
Observations	F-statistic: 20.81, p-value: 5.558e-06			
R^2 / R^2 adjusted	0.847 / 0.807			

** p<0.05 ** p<0.01 *** p<0.001*

Breusch-Godfrey test for serial correlation of order up to 1

LM test = 3.6191, df = 2, p-value = 0.1637

Bounds F-test (Wald) for no cointegration
F = 0.46199, p-value = 0.9716

Studentized Breusch-Pagan test
BP = 5.0005, df = 4, p-value = 0.2872

Shapiro-Wilk normality test
W = 0.91354, p-value = 0.07448

Ramsey's RESET Test for model specification
RESET = 0.25966, df1 = 2, df2 = 12, p-value = 0.7755

Discussion and Conclusion

In this study, we estimated the impact of the climate change indicator variables on the urbanization degree in two Egyptian Governorates using the ARDL model. The study's results yielded the significance of the maximum temperature and humidity on the urbanization degree in Dakahlia. However, the effect of climate change indicators was not significant in Ismailia, and the urbanization first lag was the only significant variable in Ismailia model. The results of our study aligned with the literature on the significant effect of high temperature. Helbling

& Meierrieks (2022) proved through their analysis that high temperature increases urbanization, especially in non-urban or agricultural areas that lack the strategies to adapt to heat stress. Additionally, the effect was insignificant in Ismailia because as the degree of urbanization exceeded 38%, the effect of temperature on urbanization became very weak (Chai et al., 2022). This study provided a preliminary analysis on the potential effect of climate change in the Egyptian GovernoratesThe study limitations are mainly the inability of analyzing the impact of the climate variables on the urbanization in the rest of the Governorates in Egypt, and the inavailability of more data in extra time points. Additionally, the future recommendation is to account for the two way relationship between urbanization and climate change suggested by the literature (Zhou et al., 2004)

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