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Economic analysis of the effect of climate change on yield of wheat crop in Egypt: case study temperature change

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This study aims to specify the effect of the minimum temperature on the wheat crop by studying the economic variables that affect the productivity, and forecasting using general trend models. Showed the instability of cultivated area of wheat crop during the study period and the annual growth rate was about 0.6%, as a result of high temperatures, which causes deterioration in soil fertility and thus affect the productivity of wheat crop has a significant annual decrease rate about 3%, Which shows the negative effect of high temperature on the decline in productivity, which made Egypt a wheat importer, so there are a correlation relation between the temperature and productivity by about 0.900, when the required cold hours are reduced, the wheat yield is reduced too during the study period. Estimation of prediction models showed that there was an expected increase in cultivated area and can be maintained in it through the use of fertilizer but yield of it will decline to about 7.7 ardeb due to the continued high temperatures as a result of climate change. The results of the prediction show that expected minimum temperatures tend to gradually increase due to global warming and try to adapt to climate change by cultivating heat-tolerant varieties in the coming years.

Keywords: Climate Change, Minimum temperatures, Wheat, Yield, Forecast, Egypt.

INTRODUCTION

Higher temperatures associated with decreasing relative humidity conditions can lead to severe drought and affect yield potential and impact crop production (Carew et al., 2017).Wheat is one of the most important grain crops in Egypt, where the country works to increase its productivity. Wheat is grown in the first three weeks of November are the most suitable dates for wheat growing. It needs fairly high temperatures at beginning of growing season, moderate temperatures for vegetative growth, relatively low temperatures at the flowering stage and relatively high temperatures in the advanced stage of the crop's life to complete grain maturity (Jasim and Alamawe, 2015a). Egypt is a developing country affected by climate change (Janjua et al., 2010), which is the change in the climatic characteristics surrounding earth due to the current increases in the concentration of gases resulting from combustion processes in the atmosphere called greenhouse gases (Fawaz and Soliman, 2015) one of these changes is the rise of atmospheric temperature and the imbalance in the amount and times of rainfall and wind patterns that characterize each region on the ground. Gaseous emissions from human activities will increase average world temperature according to Intergovernmental Panel on Climate Change (IPCC), global mean temperatures will rise 0.3°C

per decade during the next century (Abrol and Ingram, 2013a). Heat is one of the most specific climatic factors for planting and producing agricultural crops (Abrol and Ingram2013b). High temperatures may have a particularly bad effect at the time of flowering, leading to depletion of stored carbohydrates, resulting in slow leaf (Ali et al., 2017).Winter plants require minimum temperature ranging from 5 to 10^{o}C in order to come out of the dormancy period, and hence wheat, which is a winter crop, also requires long cold season in order to hasten plant development before flowering occurs, so higher temperature delay the Flowering process in wheat (Jasim and Alamawe, 2015b).Wheat has recently been affected by high temperatures(weather underground 2007-2017) during the period from 2007/2008 to 2016/2017, thus reducing the number of appropriate hours of cold needed during the growth stages and thus low productivity of wheat to 13.4 ardab (Ministry of Agriculture 2007/2008-2016/2017) which led to a defect in the quantities produced and consumed and the trend to import.

The searches aims at study the effect of high temperature due to climate change on the productivity of wheat crop and focus on the minimum temperature needed during the stages of growth and predict of the variables that effect on yield.

MATERIALS AND METHODS

This study was based on published secondary data such as data of the Ministry of Agriculture and Land Reclamation of the Economic Affairs Sector (Ministry of Agriculture 2007/2008-2016/2017).The data of the international network, including the FAO website, the site of the General Meteorological Authority and previous studies related to the subject of the study. The research was based on statistical method in analyzing data, including regression analysis to explain the relationship between economic variables, correlation analysis, and the use of time series analysis in the prediction of yield, production, cultivated area and minimum temperatures affecting wheat yield during the period (2018-2022).

RESULTSAND DISCUSSION

Economic variables of wheat yield during the study period:

Cultivated area

As show in (Table 1) of the wheat crop was unstable during the study period, as the long-run, high temperatures affect the area of wheat, where a significant annual growth rate of 0.6%, which has an effect on soil fertility and productivity. As a result, the instability of cultivated area led to a decline in wheat production from 55.2 million ardab in season 2007/2008 to 43.3 million ardab in season 2016/2017 with a significant annual decrease rate of 2.4%.

Yield

The productivity of the wheat crop has decreased from 18.08 ardab in season 2009/2010 to 13.42 ardab in season 2016/2017, with a significant annual decrease rate of 3% that shows the negative effect of high temperature on the decline in productivity, which made Egypt a wheat importer to secure domestic consumption. Although wheat is decrease in Egypt due to climate change, there is a positive impact of wheat production in Pakistan up to 2010 by increasing wheat-cultivated land due to increased rainfall (Janjua et al., 2010). While there has been a negative impact due to temperature changes on wheat production in Pakistan (Ali et al., 2017).The effect of the minimum temperature on the yield of the wheat crop during the study period.

Wheat needs appropriate temperatures during its growth stages, especially lower, which has an impact on its yield; the data for the monthly average temperature for the period 2007-2017 were shown in (Table 2), where there was a rise in temperature led to a decrease in the number of hours of cold needed by wheat germination. The research determined the minimum temperature during the planting period from December to March by estimating the number of days when the micro-grade is less than 7^{o}C, it was found that the number of hours of cold is unstable, which has an impact on yield of the wheat crop. A study of the correlation between the number of cold hours and yield, showed a positive correlation between them by about 0.900** (sig 0.01), when the required cold hours are reduced, the wheat yield is reduced too during the study period (Table 1), according to (Robertson et al., 2013a) the negative effect of the high temperature of the wheat crop, while it was found that barley and oats are heat tolerant.

Table 1. Development of economic variables of wheat crop in Egypt and Lower temperatures during the period (2007/2008 – 2016/2017)

Agricultural seasons	Cultivated area(1000 fed)	Yield (ard/fed)	Production(1000 ard)	Total hours of cold less than 7º C
2007/2008	3064	18.00	55161	243
2008/2009	3055	17.41	53200	198
2009/2010	2997	18.08	54180	225
2010/2011	3147	17.00	53511	180
2011/2012	3088	17.00	52510	171
2012/2013	3049	16.62	50668	135
2013/2014	3161	15.76	49804	126
2014/2015	3157	15.24	48122	126
2015/2016	3194	14.71	46994	117
2016/2017	3131	13.42	43350	108
Average	3114	16.33	50750	0.900**
Growth rate (%)	**0.6****	**(3)****	**(2.4)****	

(***) significant 0.001 (**) significant 0.01 ( ) brackets indicate for minus values

* Total hours of cold = Total number of days × Number of hours night.

Source: Collected and calculated from, Ministry of Agriculture and Land Reclamation. Economic Affairs Sector. Egyptian Journal of Agricultural Economics. (2007-2017). Weather Underground.2007-2017.

Table 2. Minimum monthly temperature rates during the period (2007/2008-2016/2017)

Years		2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Months	**Jan.**	10	11	11	11	10	9	10	10	10	10
	Feb.	10	10	11	12	10	10	11	10	10	11
	Mar	12	13	13	13	12	12	13	13	13	13
	Apr.	15	16	16	15	14	15	15	14	15	16
	May	18	19	19	18	17	18	19	18	19	21
	Jun.	23	23	23	22	22	22	22	21	22	23
	Jul.	25	25	25	25	25	24	23	23	24	25
	Aug	25	25	25	25	25	25	25	25	25	24
	Sep.	23	23	24	23	22	22	22	23	24	23
	Oct.	20	20	21	20	19	19	19	20	21	20
	No.	16	16	16	15	15	16	16	18	18	15
	Dec.	12	13	12	12	11	11	11	12	12	13

Source: Weather Underground.2007-2017

Forecasting the economic variables affecting the wheat crop during the seasons 2017/2018 to 2019/2020

Economic variables

Forecasting economic variables helps decision-makers in agricultural policy-making (El-Mohammedi and Abdelkrim, 2011), so the research predicted the variables that affect wheat crop using general trend models. Different models were chosen based on several criteria to choose the most accurate model that achieves the least deviations. The best of these measures is the Mean Squared Deviation (MSD) (Adhikari and Agrawal, 2013). It was found that the cultivated area has achieved an expected increase at an annual rate of growth about 1.7% during the coming period compared to the study period, it has been shown that the cultivated area can be maintained in the short-run through the use of fertilizer, which is important in increasing production and also reclamation of arable lands (Janjua et al., 2014).Despite the increase in the area of wheat but yield of it will decline during the forecast period to about 7.7 ardeb in season 2021/2022, due to the continued high temperatures as a result of climate change. Also drop in wheat production during the forecast period to reach about 29.2 million ardeb in season 2021/2022 during the coming period. (Table 3) and (Figure1), according to (Ibendahl and Kansas, 2018) estimation of the prediction shows a decrease in revenue from wheat because of high temperature.

Minimum temperatures

Fig. 1 shows that the increase in temperature affects yield of wheat during the coming period, especially the minimum temperature required by wheat during the growth stages, so the research forecast the monthly rates of the minimum temperatures during the coming period, where the temperature time series is affected by seasonal variations. Results of the prediction show that expected minimum temperatures tend to gradually increase the need for wheat during its growth due to global warming, therefore the negative impact on productivity in the coming years as shown in table 4.There is a relationship between wheat productivity and lower temperatures. Therefore, it is necessary to try to adapt to climate change by cultivating heat-tolerant varieties to (Robertson et al., 2013b) and this will help in bridging the deficit in wheat production. It is shown that wheat is needed for appropriate cold hours during its growth and shortage affects its productivity (Ali et al., 2017).

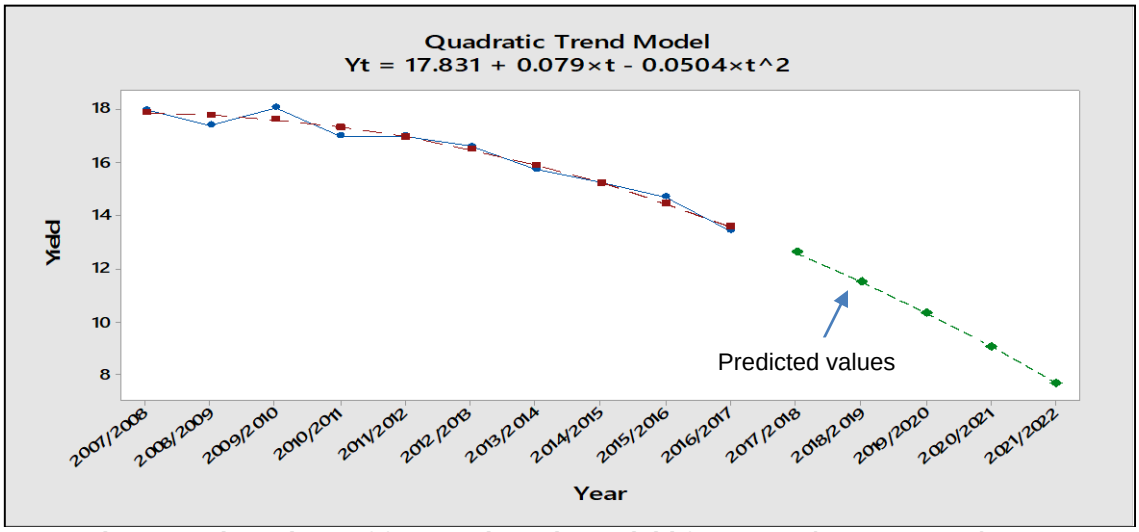

Figure 1. The values of forecasting wheat yield from 2017/2018 to 2021/2022.
Source: Compiled and calculated from forecast wheat yield by MINITAB (Karmaker et al., 2017)

Table 3. Forecasting the economic variables of the wheat crop during the period (2017/2018–2021/2022).

Agricultural seasons	Quadratic Trend Model		
	Cultivated area (1000 fed)	Yieldard/fed	Production (1000 ard)
2017/2018	3277	12.3	41525
2018/2019	3326	11.5	38832
2019/2020	3380	10.4	35886
2020/2021	3439	9.1	32686
2021/2022	3502	7.7	29231

Source: Forecast Outputs by MINITAB (Karmaker et al., 2017).

Table 4. Forecasting the monthly minimum temperatures for wheat yield during the period (2017/2018-20212022).

Years		2017/2018	2018/2019	2019/2020	2020/2021	2021/2022
Months	**Jan.**	11	12	13	14	16
	Feb.	11	12	14	15	16
	Mar.	13	14	16	18	20
	Apr.	16	17	19	21	23
	May.	22	23	25	28	30
	Jun.	23	26	29	32	35
	Jul.	26	29	33	36	39
	Aug.	26	30	33	37	40
	Sep.	25	28	31	35	38
	Oct.	21	25	27	30	33
	Nov.	16	19	22	24	26
	Dec.	14	14	16	17	18

Source: Minimum temperature prediction outputs (Table 2) using MINITAB (Karmaker et al., 2017)

CONCLUSION

Winter crops are the most affected by climate change, which causes high temperatures and thus reduce the cold hours needed for their growth. Wheat is a winter crop and one of the most important grain crops in Egypt, it needs suitable minimum temperatures during its growth stages, but as a result of climate change, temperatures have increased, affecting wheat productivity. It has been shown that the cultivated area of wheat is affected in the long-run by climate change and thus the decline in production and the trend towards importation, where can be maintained in the cultivated through the use of fertilizer. Predicting continued high temperatures in the coming years led to negative impact on wheat productivity, so the solution is to adapt to climate change and use heat-tolerant varieties

CONFLICT OF INTEREST

No conflict of interest in this study.

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AUTHOR CONTRIBUTIONS

In this study the idea was determined with the help of Dr. El-Sheikh and applied the economic research with Dr. El-khaliefa, and then Dr. Zahran reviewed and corrected the manuscript.

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