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Quantifying the climate change and its impacts on wheat productivity for decision-making support in Egypt

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Abstract

Climate change is one of the main challenging issues worldwide, with the Middle East and North Africa (MENA) region considered as one of the most susceptible to it. Egypt, located in the MENA region, is expected to suffer from several negative impacts of climate change, with increased temperature and reduced rainfall being among the worst potential perils [1]. The agriculture sector is thought to be vulnerable to the consequences of the climate change. In this study, we aimed at quantifying the climate change over a part of Egypt, with a focus on a rural area. Temperature and precipitation trends were analyzed as indicators of climate change. The CORDEX data were used to project the future climate of the study area, until 2050, using the RCP4.5 and RCP8.5 scenarios. Moreover, to assess the possible impacts on the agricultural sector, the wheat crop was chosen as a strategic crop in Egypt to study the possible effects of climate change on it. Expected wheat productivity was predicted during the period between 2025-2050 using the World Food Studies Simulation Model (WOFOST) and by applying the future CORDEX data with the two scenarios (RCP4.5 and RCP8.5). The results pointed out an expected increase in temperature and a reduction in the precipitation rate, with the RCP8.5 scenario exhibiting more pronounced changes. The wheat crop was shown to manifest the impact of climate change, indicating remarkable changes in its productivity and harvest index. These results can be useful for decision-making support process in agriculture strategy for cereal productivity.

Introduction

According to the Sixth Assessment Report of the IPCC [1], the Middle East and North Africa (MENA) region is one of the world's 'hotspots' for climate change, with long-term changes to temperatures, precipitation, and weather patterns, and a recent article [2] indicated that the MENA area will continue to suffer climatic changes "two times faster than the global average". Among the MENA region, Egypt is one of the countries most affected by climate change, with an area of 1 million km2 and a rapidly growing population, which imposes challenges on multiple systems, with the agrifood being in the heart of them, rendering it straining to meet the demands of population growth, food security and social stability.

Egypt has always been dependent on agriculture and climatic conditions. However, existing climatic trends, of expected higher temperature, lower rainfall, prolonged drought, and extreme weather events cast serious threats on the agricultural productivity and the country's capacity to sustain the local population and agrifood economy in the future.

In semi-arid or coastal locations in particular, the agricultural industry is significantly affected by the linked consequences of climate change, consisting of decreased crop productivity, salt-water intrusion, desertification, flash flood, water scarcity. Additionally, current and future effects of climate change add new pressures and risk factors to an already constrained agricultural industry.

In order to support decision-making especially in the field of agrifood, and to help with determining which strategy would be the most appropriate to mitigate the adverse impacts of climate change on agriculture, it is of crucial importance to study and document the evolution of the climate in the recent decades and predict what this evolution will be in the future.

In this study, quantification and projection of climatic changes over a rural part of Egypt was carried out, along with assessment of the expected impacts of climate change on the agricultural sector, with the wheat crop chosen as an important strategic crop in Egypt.

Methodology

Rural part of Egypt were selected for the study (Figure 1) to investigate the past and future climatic changes conditions and the associated impacts on the agriculture on these parts.

Historical weather data, consisting of temperature and precipitation, were downloaded from the NASA POWER (https://power.larc.nasa.gov) for the period between 2000 and 2020 to quantify the climatic changes in the last decades.

The CORDEX data were downloaded over the study area for the period from 2025 till 2050 to identify the projected climate using both the RCP4.5 and RCP8.5 scenarios.

The wheat crop was selected to study the foreseen effects of climate change on the agrifood sector in Egypt. Wheat crop productivity historical data, for the agriculture season of wheat in Egypt (Winter), were provided by the Agriculture Research Center, Ministry of Agriculture and Land Reclamation for the same historical period (2000-2020).

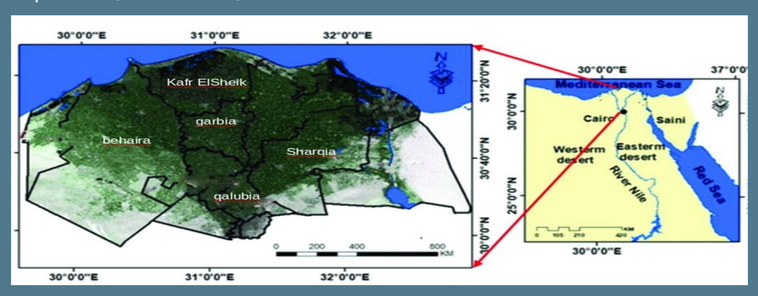


Figure 1. The study area.

Results

Over the past years (2000-2020), precipitation rate showed an overall decreasing trend, over all the locations of the study area, with some years showing above-average precipitation rate, such as 2000 and 2020, while the predicted trend of precipitation rate showed more evident decreasing trends, with the RCP8.5 scenario exhibiting less future precipitation rates (Figure 2), except for Kaf El Sheikh location, which manifested a nearly constant trend according to RCP4.5 and a slightly increasing trend according to RCP8.5.

On the other hand, analysis of the past and predicted temperature trends showed an observed increase in temperature with a further increase expected until 2050 (Figure 3).

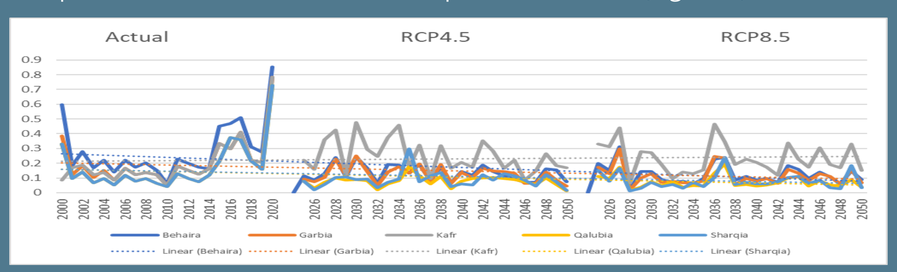
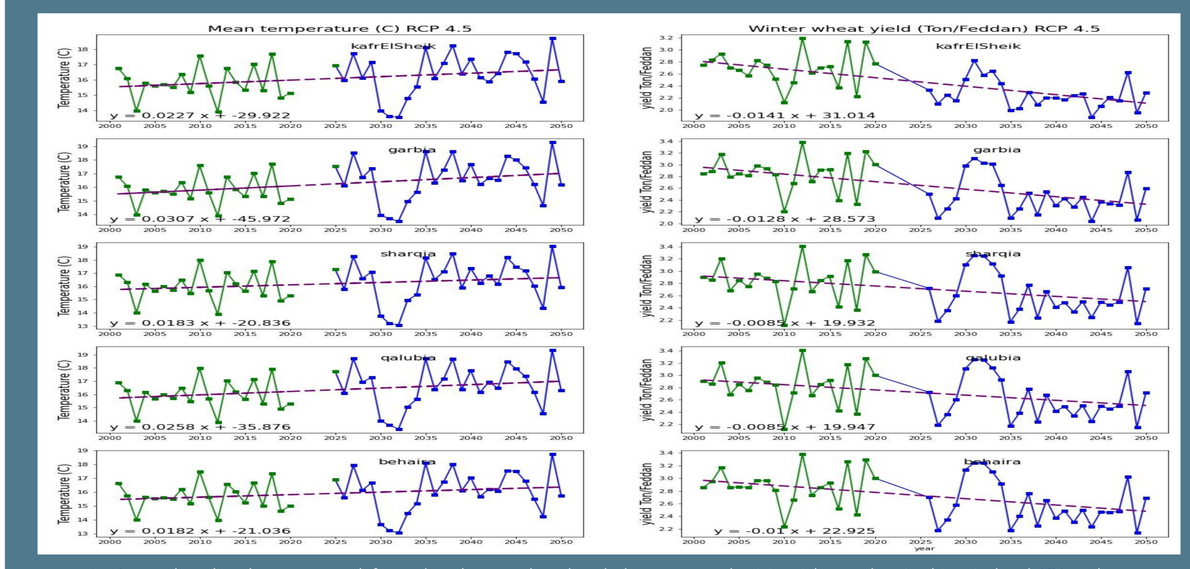


Figure 2. Past and predicted yearly averaged precipitation rate (mm/day) using historical, RCP4.5, and RCP8.5 data

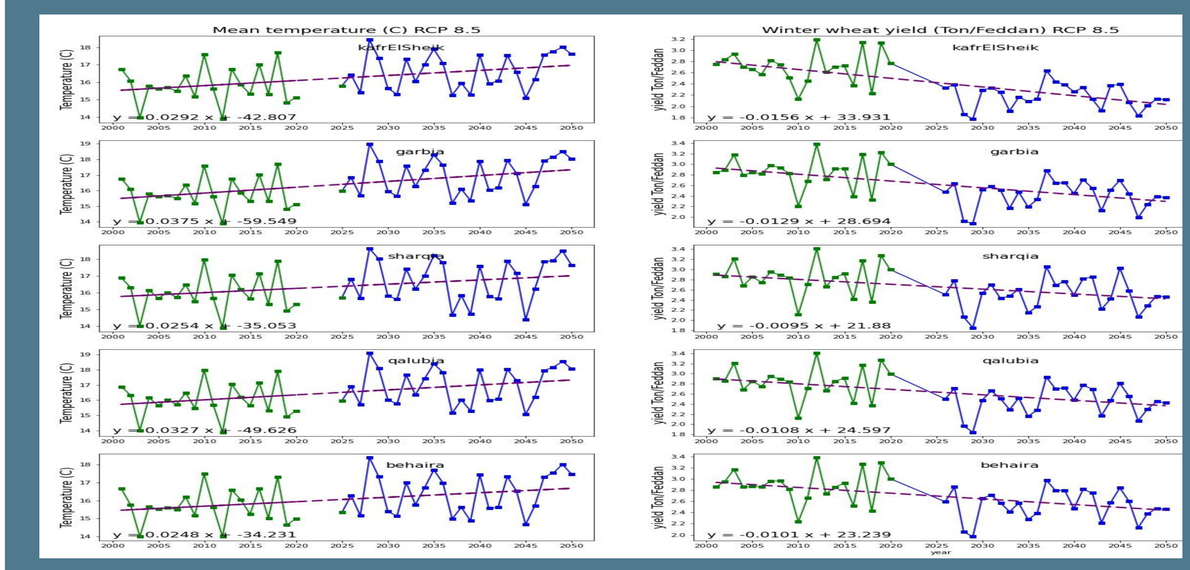
The World Food Studies Simulation Model (WOFOST) was applied using the future CORDEX data with the two scenarios (RCP4.5 and RCP8.5) to predict the future wheat crop productivity up till 2050.

Analysis of past wheat crop productivity showed an overall decreasing trend coinciding with the observed increase of temperature (Figure 3b).

Moreover, the results of applying the WOFOST model using the future CORDEX data with the two scenarios (RCP4.5 and RCP8.5) pointed out to a more decrease of wheat crop productivity reflecting the negative effect of the predicted increase of future temperature (Figure 3), with the RCP8.5 (Figure 3b) manifesting more pronounced decreased productivity.



(a) Past and predicted temperature (left panel) and past and predicted wheat crop productivity (right panel), using historical and RCP4.5 data



(b) Past and predicted temperature (left panel) and past and predicted wheat crop productivity (right panel), using historical and RCP8.5 data

Figure 3. Past and predicted (a) RCP4.5 and (b) RCP8.5 yearly temperature trend and corresponding wheat crop productivity.

Conclusion

The study investigated the past (2000-2020) and future (2025-2050) trends of precipitation and temperature, along with quantifying the wheat crop productivity being an important strategic crop of Egypt's agrifood sector.

Results indicated a varying trend of precipitation over the last years with an overall decreasing predicted trend. It was also shown that was a clear increasing trend of past temperature and an expected further increase in the future temperature.

Wheat crop productivity data analysis indicated a decrease past and future trend, which could be clearly linked to the increasing trend of temperature. Moreover, the foreseen decreased trend of precipitation adds more pressure and further worsens the situation of decreased productivity.

The wheat crop exhibited signals of being affected by the climate change over the area of study. These results shed light on the importance of tackling climate change and could support decision-making especially in the zone of adaptation strategies and building preparedness and response capacity in the agriculture sector.

More research is urgently needed in this area to further determine the impacts of interlinked climatic changes on the agrifood system.

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