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Potential Impact of Climate Change on Wheat Production in Cambridgeshire, UK

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Abstract

Wheat is a major food crop in the UK and worldwide. Moreover, the UK grows winter wheat extensively due to suitable climatic conditions. However, the frequency and severity of extreme weather events are likely to rise with global warming. Droughts and high temperatures are known to have substantial impacts on crop growth. Thus, this study accessed the potential impact of climate change on wheat production in Cambridgeshire in the 2080s, specifically assessing the potential impacts from drought, heatwaves, and effect on fertility. Data analysis includes 5 different runs (runs 96, 97, 98, 99, 100) of the weather Generator sourced from the UKCP09 website. The result shows that droughts and high-temperature days will be more frequent in future summer months, and heatwaves more frequent and longer in duration. It is likely that high temperatures will have the largest impact on wheat production in a future climate as opposed to drought, and the risk of reduction in fertility will also increase. In all, the study presents a slight increase in drought and a significant increase in temperature in the future, while the extremely high temperature will increase the risk of crop losses. However, early maturity appears to be more beneficial in the future due to increasing temperature.

Keywords

Wheat Production, Climate Change, UK

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1. Introduction

Wheat is one of the most important food crops worldwide behind only corn and rice and is an essential source of carbohydrates to millions of people [1]. Winter wheat (*Triticum aestivum*) is currently the most widely grown arable crop in the United Kingdom. The UK climate has been suitable for wheat for years. Each year, 14 – 15 million tonnes of wheat are produced and about 30% of them are supplied to milling industry in the UK or exporting to overseas [2]. The yields of winter wheat are sensitive to precipitation and maximum temperature. It was reported that the yield variability is strongly associated with the average temperature from May to June, the precipitation in November and the minimum summer temperature [3-4]. Observations and future projections suggest that the UK climate is changing, and the temperature is increasing and may continue to rise. In response to increased amounts of short-term temperature extremes, and prolonged droughts, it is of importance to predict the impact that this will have on crop production; to assist in mitigating any potential risks for production [5-6]. Winter wheat production involves planting seed in the autumn, overwintering in the ground and then a period of growth in the spring and early summer. Drought and high temperature adversely affect photosynthesis in wheat as it grows best in intermediate temperature.

The study assessed the potential impact of climate change on wheat production in Cambridgeshire, a county in the East of

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England, located in the most agriculturally productive region in the UK, bordering Lincolnshire to the north, Suffolk to the east, Essex and Hertfordshire to the south, and Bedfordshire and Northamptonshire to the west. Specifically, the study sought to ascertain the likelihood of drought, impact of heatwaves and the impact of hot days in the 10-days before maturity, comparing the baseline to the future scenario using data generated from the UKCP09 website [7]. The UKCP09 weather generator is based on a stochastic model that stimulates future weather conditions and produce synthetic daily time series of weather data.

2. Methods

The study analysed 5 out of 100 runs (96, 97, 98, 99, and 100) created using the high emissions scenario for Cambridgeshire in the 2080s (2070-2099) with baseline data from 1970s (1961-1990). The data were analysed with Microsoft Excel using the 'IF' statement and PivotTable.

Data Analysis

Dry days; "IF (total precipitation=0, 1, 0)" was used while the data was summarized with the PivotTable, 'month' selected for the Rows and 'Dry days' for the Sum of Values, the output was divided by 30 (average for a year).

Dry runs; "IF (total precipitation =0, 1, 0)" was used to calculate the first value while "IF (total precipitation =0, previous dry day+1, 0)" was used for the rest values. The data were summarized with the PivotTable, 'Dry runs' selected for the Rows VS 'Dry runs' for the Count of Dry runs. (0 dry days row) and (1 dry day) were ignored, the rest values were divided by 30.

Hot days ≥ 25°C; "IF (temperature max >24.9, 1, 0)" was used while the data was summarized with the PivotTable, 'month' selected for the Rows and 'Hot days' for the Sum of Values, the output was divided by 30.

Hot runs ≥ 25°C; "IF (temperature max >24.9, 1, 0)" was used to calculate the first value while "IF (temperature max >24.9, previous hot day+1, 0)" was used for the rest values, the data were summarized with the PivotTable, 'Hot runs' selected for the Rows VS 'Hot runs' for the Count of Hot runs. (0 hot days row) and (1 hot day) were ignored, the rest values were divided by 30.

Hot days ≥ 26°C (10 days preceding the maturity date); the baseline and future scenario with (maturity date = 160) was calculated using "IF (day count<150, 0, IF (day count >160, 0, IF (temperature max >25.9, 1, 0)))" while "IF (day count <120, 0, IF (day count >130, 0, IF (temperature max >25.9, 1, 0)))" was used to calculate the future scenario (maturity date = 130) the final values for the maturity dates were divided by 30.

3. Results

Figure 1: Monthly distribution of dry days.

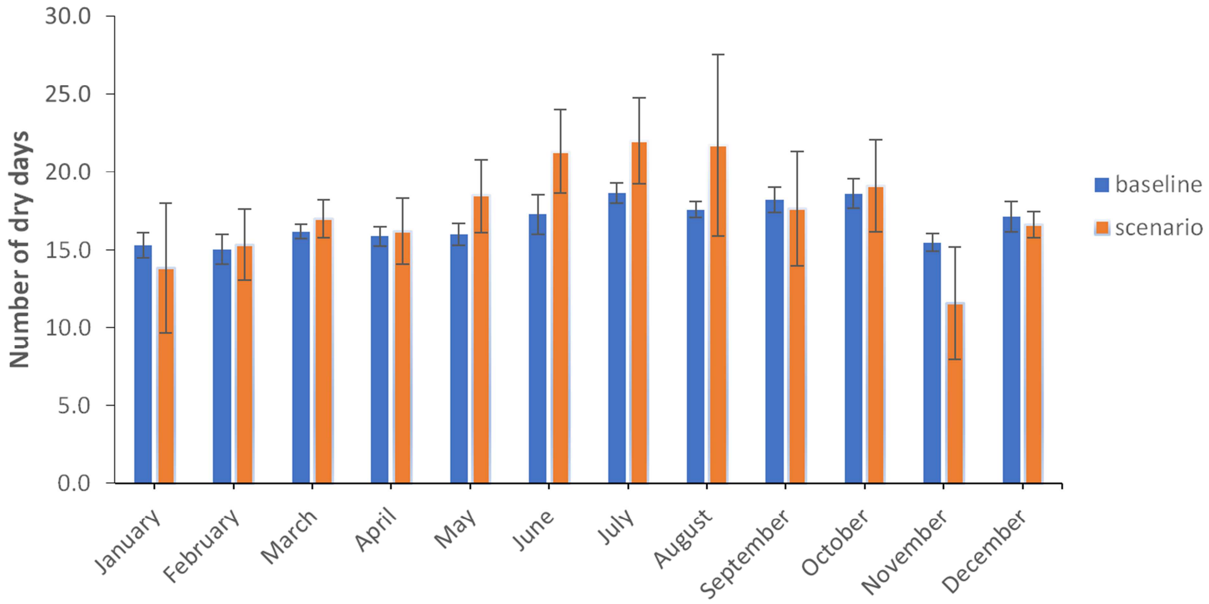

Figure 1. Compares the monthly distribution of dry days per month in the baseline to the future scenario throughout the year. This shows an increase in the number of dry days in the summer (2080s).

Figure 2: Distribution of the duration of dry spells.

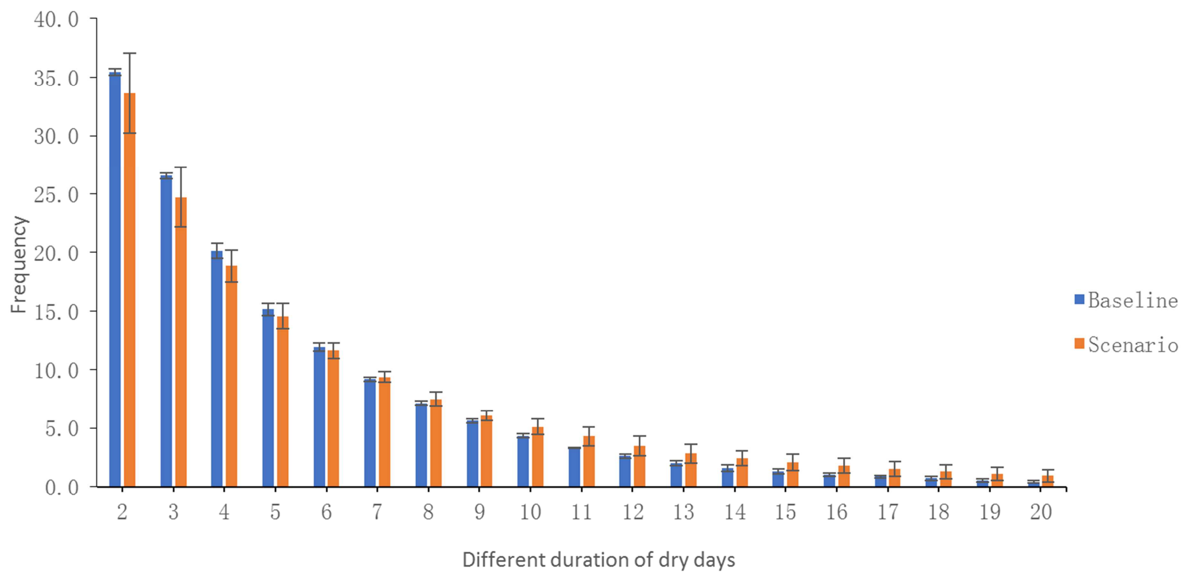

Figure 2. The distribution of different duration of dry days. This shows that there will be a longer period of drought in the future scenario (2080s).

Figure 3: Monthly distribution of hot days (Max Temp ≥ 25°C).

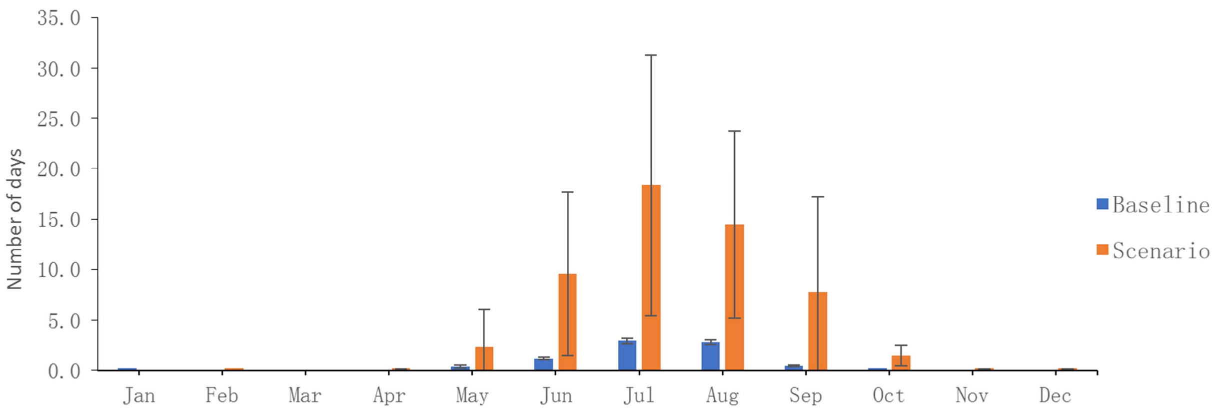

Figure 3. The average amount of hot days at a maximum temperature of 25℃ and above in different months. This shows a significant increase in the number of hot days and more extreme weather events in the future (2080s).

Figure 4: Frequency of hot days in heatwaves (Max Temp ≥ 25°C).

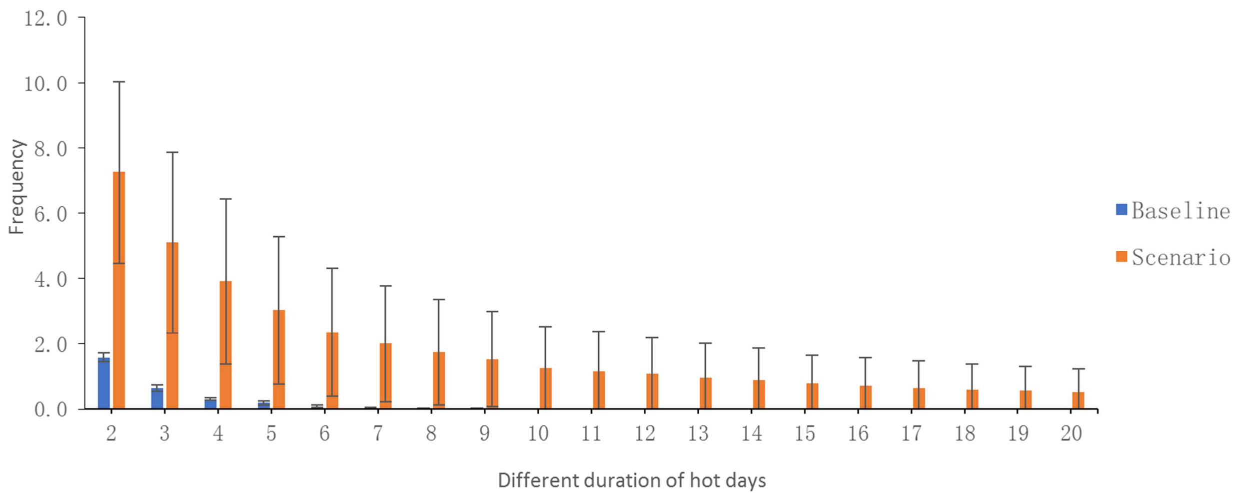

Figure 4. The distribution of average hot days in a heatwave. This shows an increase in the period and occurrence of heatwaves in the future scenario (2080s).

Table 1. Frequency of hot days and fertility (Temp ≥ 26°C in the 10 days before maturity).

	Control (150-160)	Scenario (150-160)	Scenario (120-130)
Average	0.22	2.28	0.59
Standard Deviation	0.04	2.22	0.87

Table 1 compares the frequency of hot days in the 10 days before maturity in the baseline to the future scenario with the same maturity date (Day 160) and an earlier maturity date (Day 130). This shows a significant increase in the frequency of hot days in future scenarios (2080s) compared to the baseline.

4. Discussion

In the UK, winter wheat is always planted in October and harvested in August next year, which experiences 3 development phases including foundation, construction, and production [8]. The growth and yields of winter wheat are susceptible to daily temperature and precipitation [9]. Especially, the maximum temperature and precipitation in May and June would impact the ear formation and grain filling stage separately, which would be significant drivers of yields [3].

Takac and Siska [10] mentioned the importance of soil water content to the yield of winter wheat cross the whole growing season. Precipitation is a direct factor that would influence the water content in the soil. The weather data analysis in this study shows that the future climate will have dryer summers, wetter winters, more high-temperature days, with longer and more frequent heatwaves.

4.1. Likelihood of Drought

Figure 1 shows a slight increase in the number of dry days between April and August in the future scenario, indicating wetter winter. Hence the major increase in dry days in the month of June, July, and August in the future scenario might not have a significant effect on wheat [11-12]. Figure 2 shows that the frequency of the duration of dry runs decline steeply as the periods of dry spell extends in the baseline and the future scenario (2080s), however, the baseline maintains a high duration of dry spell lasting for 2 to 6 days, while the future scenario had a higher frequency of dry spell lasting for 7 days and above, the change in frequency of dry spell lasting for 7 days and above might increase crop losses due to drought in the future. This suggests a temperate drought in the future scenario compare to the baseline. Nevertheless, there might be a minimal risk of crop losses due to drought in the future (2080s) as the study did not analyse the amount and intensity of precipitation in the study area.

4.2. Impact of Heatwaves

Figure 3 shows a significant increase in the number of hot days with temperature ≥ 25°C between June and September in the future scenario when compared to the baseline. This will hasten the decline of photosynthesis and leaf area [13]. The data presented in figure 4 is an indication of increased length of heat waves with temperature ≥ 25°C in the future scenario. The risk of increased crop losses due to hot weather in the future scenario is on the high side, which could be as a result of a reduction in water-use efficiency and disease infestation such as rust, root rot, and insects.

4.3. Hot Days and Fertility

Table 1 shows that the baseline had an occurrence of approximately 0.22±0.04 hot days while the future scenario with the same maturity date (Day 160) had 2.28 ±2.22 hot days with a temperature ≥ 26°C in the 10 days preceding maturity, the future scenario with early maturity date (Day 130) had an occurrence of approximately 0.59 ±0.87 hot days. Hence the future scenario with (maturity date = 160) will experience more frequent high temperature which may be too hot, resulting in a decrease in crop yield [9], while the future scenario with early maturity date (Day 130) appears to be more beneficial in the future, as the maturity duration also decreases. This agrees with previous studies which identify that temperature increase mostly accelerates phonological development for all crops and specifically shortened the time to maturity [11, 14, 15].

5. Conclusion

The climate of Cambridgeshire in the 2080s would be hotter and a little bit dryer than the 1970s. In other words, heat stress not drought will be the most significant limiting factor in the future for wheat production as hot days and heatwaves would happen more frequently in winter wheat growing season. There is a slim chance of increase crop losses due to drought in the future scenario. However, there is a possibility of an increase in crop loss due to hot weather in the future scenario, depending on intensity and persistence. The early maturity date (Day 130) appear to be more beneficial in the future as the maturity duration also decreases due to hot weather condition. Generally, high temperature without water stress might have little effect on fertility, but extremely high temperature will increase crop losses in the future. Increase variability indicates more extreme events. Therefore, scientists and breeders should focus predominantly on developing techniques and wheat varieties for the UK that have improved tolerance high temperatures, especially around the flowering and anthesis periods.

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