Climate Long-Term Trends Impacting Wheat Production Systems in Kansas

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Summary
Winter wheat production is of major importance in Kansas. The purpose of the study was to verify the evidence of climate change in a long-term weather data series from Wellington and Parsons, KS, to understand whether climate change has been affecting yield production.

Introduction
In the last 10 years, 8 million acres of wheat were planted resulting in 320 million bushels, which highlights wheat as a major crop for Kansas. In addition, wheat products and derivatives can be found in many foods, including baked goods, baking mixes, and batter-fried and breaded foods. Future climate and weather may be different due to climate changes, which may affect both crop growth and U.S. farmers' profitability.

Assuming that climate change would affect crop yield in the future, this project aims to analyze long-term climate data series in the state of Kansas to understand the impact that climate change has already caused on the weather variables. Trends and breaks in the weather data were studied using Mann-Kendall and Pettitt non-parametric statistics equations, respectively. In addition, we analyzed the crop yield trend using a process-based crop model (DSSAT-CERES-Wheat) to check if and how the weather has already affected long-term wheat yields. This study demonstrated the importance of knowing whether climate change is affecting crop growth and development. Thus, with this knowledge, cropping systems can be adapted to upcoming climates, ensuring food security.

Experimental Procedures
In this study, weather data from two weather stations, one in eastern (Parsons) and another in central (Wellington) Kansas were used to provide a broader geographical representation of the state. Wellington's weather station data were collected from 1865 until 2021 and Parson's from 1925 until 2021.

To study climatic trends, the weather data (maximum and minimum temperature and rainfall) were analyzed to identify the weather pattern through years and variations in a

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specific weather variable at a certain time. Due to the amount of data, the analyses were done using Python language.

Two different statistical procedures were used to analyze the weather data: Mann-Kendall and Pettitt, respectively. Mann-Kendall's (Mann, 1945; Kendall, 1975) equations were used to identify data trends, highlighting whether any variable presented a pattern change. After that, Pettitt's test (Pettitt, 1979) was used to identify the exact point when the variation in the weather pattern was statistically different. In this manuscript, we are presenting the results of Mann-Kendall and Pettit analyses. Later, this study will evaluate the impact of climate changes using these same climatological historical series, simulating the wheat yield over time using process-based crop models (DSSAT-Ceres-Wheat).

Results and Discussion

The Mann-Kendall test for Parsons showed the existence of a trend in the three variables analyzed. Maximum and minimum temperatures showed a decreasing trend and rainfall increased. In Wellington, the analyses pointed to different results for the three variables. The maximum temperature highlighted the existence of a decreasing trend, the minimum temperature did not present trends, and rainfall data had an increasing trend. Based on these results, the climate has changed in central (Wellington, Figure 1) and eastern (Parsons, Figure 2) Kansas.

For the variables minimum and maximum temperature, the decreasing trend represents negative slopes, which indicate a reduction in temperature values, and in the same way, the increasing trend represents positive slopes, indicating a temperature rise. The observed results for Parsons showed the trend of reduced minimum and maximum temperature values. For Wellington, only the maximum temperature showed the existence of a trend but also indicated decreasing values over those years.

Precipitation can be analyzed the same way as the temperatures were. The increasing precipitation trend was assumed to represent positive slopes, and the increase in rainfall. Both locations used in this study showed increasing values for precipitation, and those values match others found in studies from this same area.

In a study of analysis of temporal and spatial distribution for precipitation in Kansas, Rahmani et al. (2015) used data from 1890 to 2011 from 23 stations across the state to determine trends, gradual changes, and abrupt changes in the historical series using methods of Mann-Kendall, CUSUM, and Pettitt. The results showed that all but two stations had an increase in rainfall and that those kinds of increases tended to rise inside the state from west to east. From that we can assume the increase in rainfall in both studies' areas. Also, this same study showed significant change points in 12 of the 23 weather stations analyzed. Ahn et al. (2016) used those same methods for the analysis of trend and variability in hydrological extremes in the U.S. and found significant increasing trends for most of the weather stations.

Pettit's analysis shows the exact breakpoints (statistical change) at each variable (maximum and minimum temperature and rainfall) at the two locations in our study. All the weather stations analyzed demonstrated abrupt changes in the data series. It included the minimum temperature data for Wellington (Figure 1A), which despite not presenting a trend with the Mann-Kendall method showed a breakpoint at 1970, indicating the possibility of change in the data. For Wellington, the maximum temperature showed a breakpoint in 1967 (Figure 1B) and rainfall in 1957 (Figure 1C). For Parsons, the minimum temperature had breakpoints in 1975 (Figure 2A), the maximum temperature in 1972 (Figure 2B), and rainfall in 1939 (Figure 2C). Those results correspond to those reported by Rahmani et al. (2015) who demonstrated breakpoints in the available weather data for stations from 1940 to 1980.

These changes in temperature and rainfall may modify wheat physiological responses during the growing season in Kansas, which may or may not affect wheat yield in central-east Kansas. These climatological series will be used in the DSSAT-Ceres-Wheat model to evaluate the impact in wheat yield.

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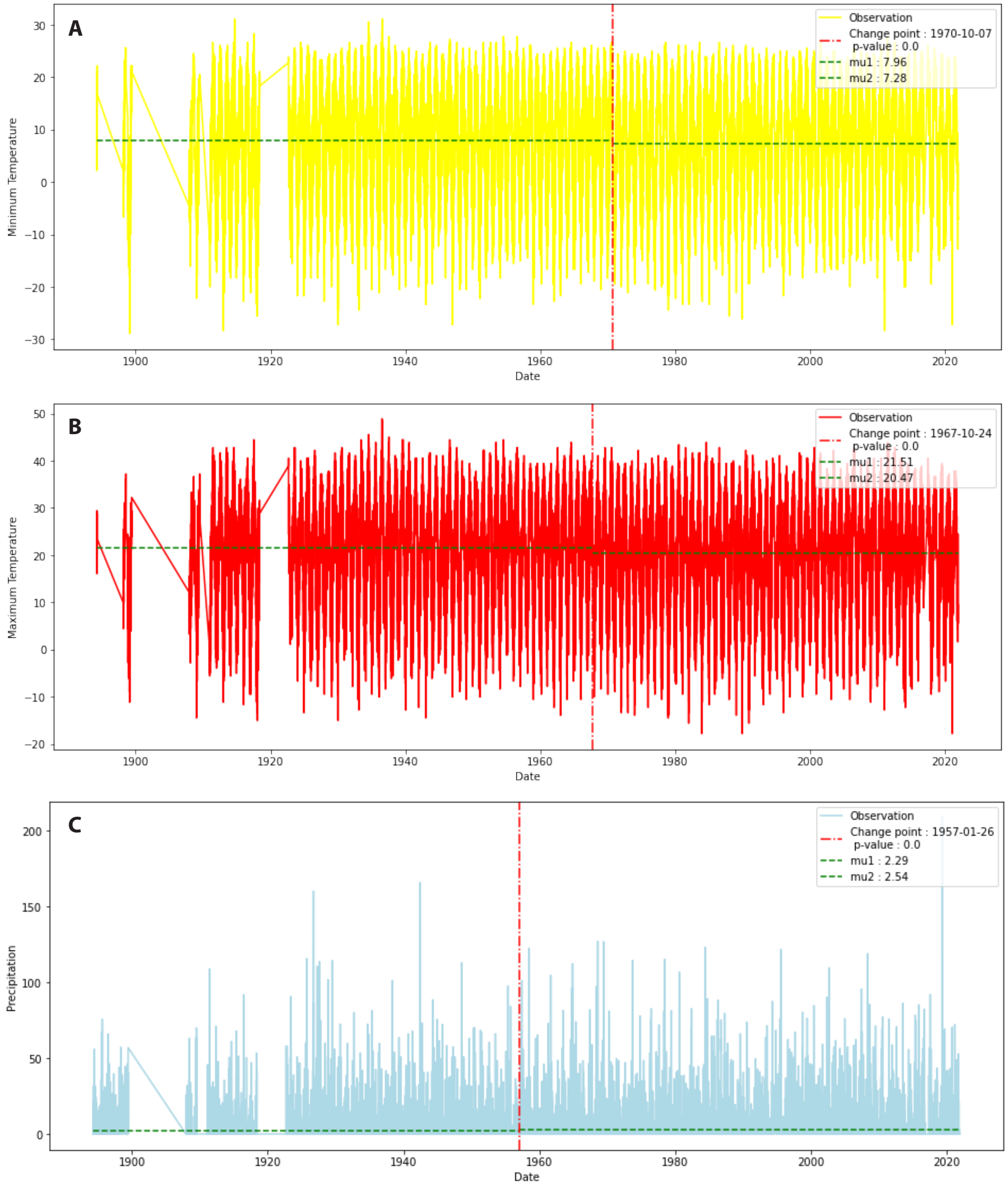

Figure 1. Minimum (A) and maximum (B) temperatures (Celsius), and precipitation (C; millimeters), respectively, in Wellington from 1895 to 2021. The dashed line highlights the change point.

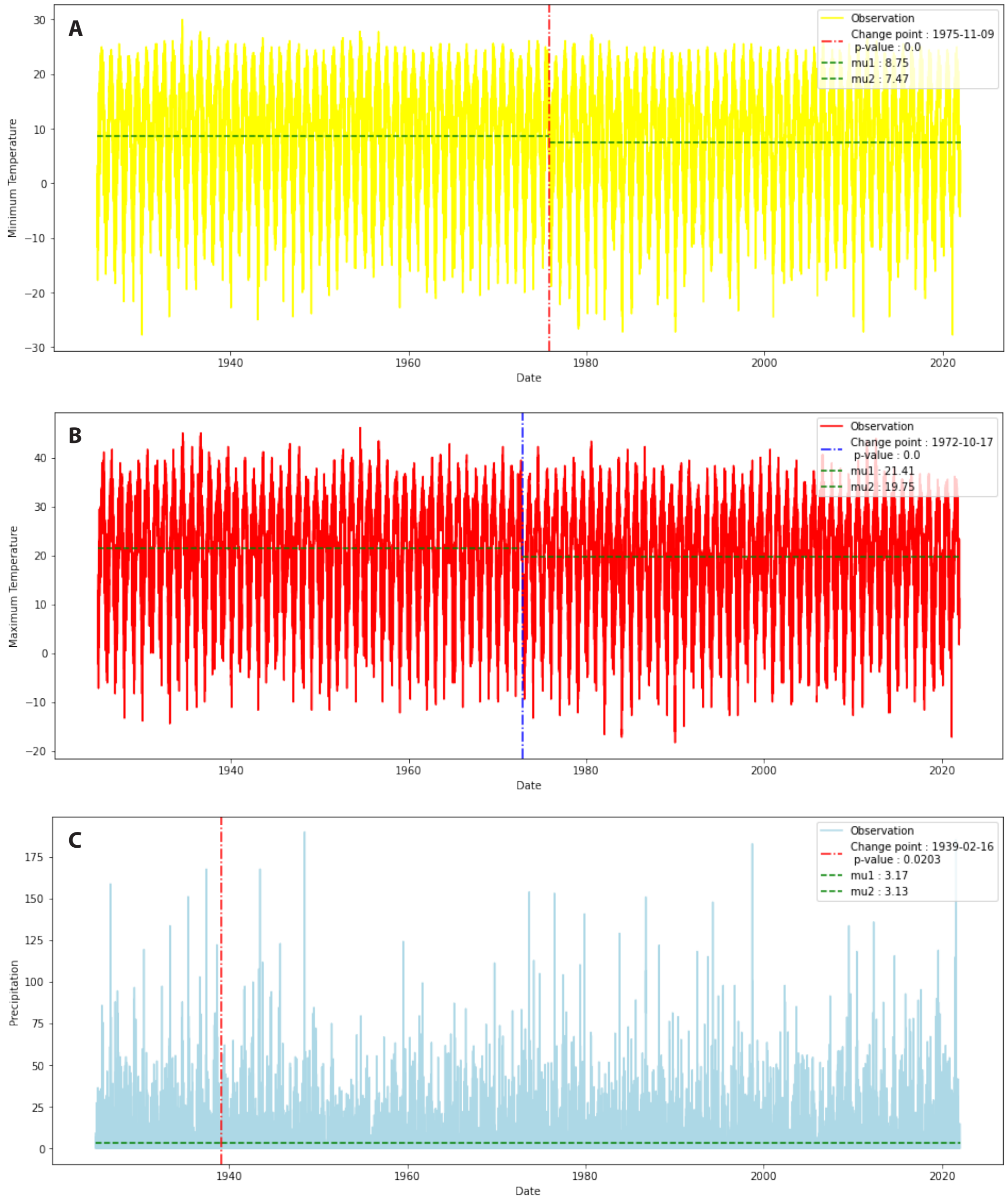

Figure 2. Minimum (A) and maximum (B) temperatures (Celsius), and precipitation (C; millimeters), respectively, in Parsons from 1925 to 2021. The breakpoints are highlighted by the red dashed line for A and C, and by a blue dashed line in B.