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^ Bruno Basso and others at Michigan State University are working with farmers to test the use of Unmanned Aerial Vehicles to remotely and rapidly measure various plant and crop indices, such as nitrogen and phosphorus levels, crop disease, and much more.

Predicting the Impact of Increasing Temperatures on Corn Yield

BY BRUNO BASSO AND RYAN NAGELKIRK

Plants view time differently than people, not in minutes, hours or days, but in growing degree-days. Growing degree-days (GDD) are not actually days, but rather the accumulation of daily heat (temperature) units necessary for crops to develop, produce new leaves, reach the reproductive stage, and ultimately mature. The total number of GDD required to reach each of these steps is pre-determined by the genetic characteristic of the cultivar (i.e. corn hybrid). Corn, for example, requires the accumulation of 52 degree-days for a new leaf to appear, or about 3,000 degree-days from planting to maturity for a 120-day corn hybrid. Degree-days are calculated by subtracting the plant base temperature (in the case of corn, 50° F) from the mean air temperature for each single day of the growing cycle. This means that the life span of a 120-day corn will vary depending on temperatures within the growing season.

Crop simulation models have been developed and used for nearly 40 years to predict and model crop yields, taking into consideration the interaction between management, weather, soils and genotype characteristics used in a particular field experiment. Crop simulation models predict the total biomass of a crop as the product of average growth rate (affected by photosynthesis) and growth duration (affected by optimum minimum and maximum temperatures). Changes in temperature, particularly very high or especially low temperatures as predicted by future climate scenarios, will have an effect on crop yield.

Highest yields of annual crops are achieved in cooler temperatures that maximize the duration of plant growth in the absence of any stressors. Under current climate projections, temperatures will rise by approximately 4.4° C (10° F) by the end of the century. That temperature increase for the state of Michigan, for example, can be envisioned as a shift in geographic locations (i.e. equivalent to the current mean temperatures of Indiana, Missouri or Oklahoma (Karl et al., 2009). The increase in temperatures will shorten the growing cycles, causing yield to decline. At the same time, in many cool places like the Midwestern United States, the last and earliest day of frost will change in a way that the total growing season could be longer by planting earlier and harvesting later (Fig. 1). These trends already have been observed over the last century: rising temperatures have extended the growing season two days per decade.

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In an effort to understand the likely effects of climate change on agriculture, maize and soybean yields in the Maumee River Watershed, in Ohio, were simulated using the Systems Approach to Land Use Sustainability (SALUS) crop model. SALUS calculates daily crop growth in response to changing climate, soil, and management conditions. We tested the hypotheses that despite any positive effects related to fertilization effects of increased carbon dioxide (CO_2) in the atmosphere, longer and warmer growing seasons will lead to excessive water- and heat-stress, resulting in lower yields under current management practices. The SALUS model was tested against measured county yield data and demonstrated the ability to reproduce the observed data and yield variation over the years (Fig. 2).

Corn yields in the Maumee River Watershed, Ohio, were modeled using low (B1) and high (A2) CO_2 emission scenarios from the Special Report on Emissions Scenarios (SRES) (Fig. 3). The middle line of each box represents the median yield for that scenario. The lines above and below that (the ends of the box) are the first and second quartile of the data (50 percent of the yields lie within the box). The ends of the bars represent the maximum and minimum values predicted within the watershed.

Decreased yield is projected for both scenarios, with the higher emissions scenarios showing the greatest decline. Yield is predicted to decrease under both scenarios and over time, with more drastic yield decline by the end of the century.

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FIGURE 1 | POTENTIAL LENGTHENING OF GROWING SEASON DUE TO INCREASE IN TEMPERATURES

As a simple demonstration, when average daily temperatures are uniformly increased by the amount projected by the A1B SRES scenario (4.4° C), the growing season in northwest Ohio increases by 59 days.

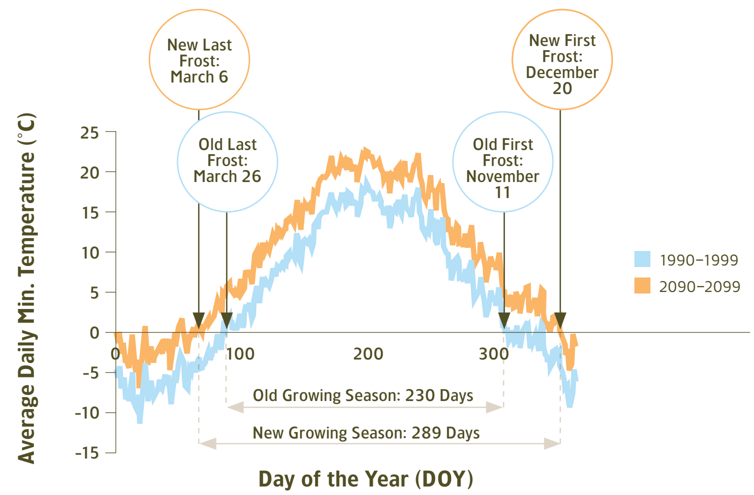

FIGURE 2 | COMPARING SALUS, A CLIMATE MODEL, TO ACTUAL YIELDS

Results are shown for backcasting yields in a single county within the Maumee River Watershed, Ohio. SALUS (orange) was able to match the direction and magnitude of change recorded by the USDA Agricultural Survey (blue) for many of the years.

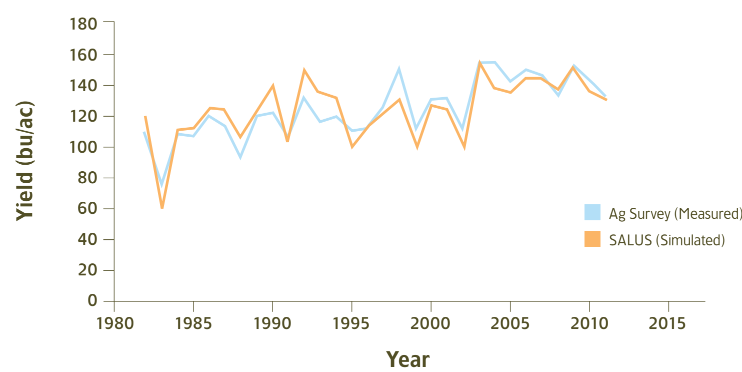

FIGURE 3 | MODELED EFFECT OF CLIMATE CHANGE ON CORN YIELD IN THE MAUMEE WATERSHED