How will Climate Change Affect Agriculture? Impacts Over the Next 10-30 Years

Jerry L. Hatfield
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Impacts over the next 10-30 years
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Climate Changes

- Increasing temperature of 1.2°C (2.2°F) over the next 30 years
- Increasing CO$_2$ of 60 ppm over the next 30 years
- Increasing variability in precipitation
- There will be increasing variation in temperature and precipitation within and among years
Temperature Changes

Annual Mean Temperature Anomalies
Precipitation Changes

Annual Precipitation Anomalies
Corn Production in the US

Corn for Grain, Harvested Acres: 2002

United States Total
66,230,523
Forage Production

Forage - Land Used for All Hay and All Haylage, Grass Silage, and Greenchop, Harvested Acres: 2002

United States Total: 94,041,337

Acres
- Less than 5,000
- 5,000 - 19,999
- 20,000 - 29,999
- 30,000 - 49,999
- 50,000 - 74,999
- 75,000 or more

U.S. Department of Agriculture, National Agricultural Statistics Service
Beef Cow Inventory

Beef Cows - Inventory: 2002

United States Total
33,398,271

1 Dot = 5,000 Beef Cows
Temperature Responses

- Plants
- Animals
Plant Temperature Responses

- Variation among plants
- Variation among plant phenological stages
  - Germination
  - Vegetative Growth
  - Reproductive Growth
- Difference between air temperature and plant temperatures
## Temperature

<table>
<thead>
<tr>
<th>Crop</th>
<th>Optimum Temp (C)</th>
<th>Temp Range (C)</th>
<th>Failure Temp (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Veg</td>
<td>Reprod</td>
<td>Veg</td>
</tr>
<tr>
<td>Maize</td>
<td>34</td>
<td></td>
<td>18-32</td>
</tr>
<tr>
<td>Soybean</td>
<td>30</td>
<td>26</td>
<td>25-37</td>
</tr>
<tr>
<td>Wheat</td>
<td>26</td>
<td>26</td>
<td>20-30</td>
</tr>
<tr>
<td>Rice</td>
<td>36</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Cotton</td>
<td>37</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Tomato</td>
<td>22</td>
<td>22</td>
<td>22-25</td>
</tr>
</tbody>
</table>
# Temperature

<table>
<thead>
<tr>
<th>Crop</th>
<th>Temp Range (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Veg</td>
</tr>
<tr>
<td>Watermelon</td>
<td>18-35</td>
</tr>
<tr>
<td>Cucumber</td>
<td>12-30</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>12-30</td>
</tr>
<tr>
<td>Onion</td>
<td>7-30</td>
</tr>
<tr>
<td>Potato</td>
<td>5-25</td>
</tr>
<tr>
<td>Broccoli</td>
<td>5-25</td>
</tr>
</tbody>
</table>
Temperature Responses

- Occurrences of higher temperatures will cause faster phenological development.
- Higher temperatures will affect reproductive development because of the sensitivity of pollen survival to temperature.
- Yields will be impacted because of shorten reproductive periods.
## Climate Impacts

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Soybean-Midwest</td>
<td>+2.5%</td>
</tr>
<tr>
<td>Soybean-South</td>
<td>-3.5%</td>
</tr>
<tr>
<td>Wheat</td>
<td>-6.7%</td>
</tr>
<tr>
<td>Rice</td>
<td>-12.0%</td>
</tr>
<tr>
<td>Sorghum</td>
<td>-9.4%</td>
</tr>
<tr>
<td>Cotton</td>
<td>-5.7%</td>
</tr>
<tr>
<td>Peanut</td>
<td>-5.4%</td>
</tr>
<tr>
<td>Bean</td>
<td>-8.6%</td>
</tr>
</tbody>
</table>
Forages

- Increased temperature will hasten development and increase the length of the growing season
- Impact on forage quality
Fruits and Nuts

- Warmer temperatures will cause earlier bud break or flowering in the spring
- Warmer temperatures will cause faster development
- Warmer temperatures could impact chilling requirements for many plants
- Increase potential problems when warm temperatures cause early development and then turns cold
Animals

- Optimum temperature is a very narrow range (thermoneutral zone) is which animal does not need to alter behavior or physiological function to maintain core temperature.
- Responses include panting, shivering, reduced feed intake, increased (cold) or decreased (warm) metabolic rates.
- Any of these responses will impact productivity (meat, milk, or reproduction).
Temperature Response
Impacts on Swine Production

Days for swine to grow from 50 to 110 kg
Impacts on Beef Production

Changes in days to reach market weight
Impacts on Milk Production

Effects on milk production due to temperature increases
Temperature Effects on Reproduction

- Dairy cows reduced conception rate of 4.6% for Thermal/Humidity Index values above 70
- Beef cows reduced conception rate of 3.2% for Thermal/Humidity Index values above 70
- Beef cows 3.5% reduction in conception rate for each degree of temperature increase above 23.4°C
Episodic Temperature Events

- High temperature episodes cause stress in animals which affects rate of gain, milk production.
- Cold temperature episodes affect feed consumption and survival of young animals.
- Temperature extremes lead to economic loss on order of millions of dollars.
Carbon Dioxide
Responses

- Increasing CO$_2$ will increase plant growth
- Difference between C3 and C4 plants
- Increasing CO$_2$ will increase water use efficiency because of increased growth per unit of water transpired
# CO₂ Responses

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield Change</th>
<th>ET Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>+1.0</td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>+7.4</td>
<td>-2.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>+6.8</td>
<td>-1.4</td>
</tr>
<tr>
<td>Rice</td>
<td>+6.4</td>
<td>-1.7</td>
</tr>
<tr>
<td>Sorghum</td>
<td>+1.0</td>
<td>-3.9</td>
</tr>
<tr>
<td>Cotton</td>
<td>+9.2</td>
<td>-1.4</td>
</tr>
<tr>
<td>Peanut</td>
<td>+6.7</td>
<td></td>
</tr>
<tr>
<td>Bean</td>
<td>+6.1</td>
<td></td>
</tr>
</tbody>
</table>
ET effect due to CO₂

Evapotranspiration

- Ample N, Ample H₂O
- Low N, Ample H₂O
- Ample N, Low H₂O

- Wheat (C₃ grass)
- Rice (C₃ grass)
- Sorghum (C₄ grass)
- Poplar (woody)
- Cotton (woody)
- Sweetgum (woody)
- Soybean (C₃ legume)
- Potato (C₃ forb)
- All C₂ & C₄

When water limiting over seasonal time frame, little change in ET because plants use all water available.
Rangeland Responses

**Tallgrass Prairie (840 mm)**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>49%</td>
<td>33%</td>
<td></td>
<td></td>
<td>17%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Shortgrass Steppe (320 mm)**

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28%</td>
<td>43%</td>
<td>17%</td>
<td>95%</td>
<td>30%</td>
</tr>
</tbody>
</table>

**KEY**

- **CO2**
  - Ambient
  - Elevated

**PRECIP**

- **Dry**
- **Normal**
- **Wet**
Precipitation

- Variable precipitation will increase potential soil deficits
- Decreased soil water availability will offset the positive impacts of CO$_2$ and exaggerate the effect of increasing temperatures
Field Scale Variation

Dallas S. strip 5
70#N R/G

Dallas S R/G
Strip 6 170#N
Implications on Yield

- Yield patterns within fields are caused lack of soil water during the grain-filling period.
- Yield variation in corn can be as large as 100 to 150 bu/A within a field due to soil water holding capacity.
## Forage Quality

<table>
<thead>
<tr>
<th>Change</th>
<th>Examples of positive effects on forage quality</th>
<th>Examples of negative effects on forage quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-form distributions</td>
<td>Decrease in proportion of woody shrubs and increase in grasses in areas with increased fire frequency.</td>
<td>Increase in the proportion of woody species because of elevated CO₂, increases in rainfall event sizes and longer intervals between rainfall events.</td>
</tr>
<tr>
<td>Species or functional group distributions</td>
<td>Possible increase in C₃ grasses relative to C₄ grasses at elevated CO₂.</td>
<td>Increase in the proportion of C₄ grasses relative to C₃ grasses at higher temperatures. Increase in abundance of perennial forb species or perennial grasses of low digestibility at elevated CO₂. Increase in poisonous or weedy plants.</td>
</tr>
<tr>
<td>Plant biochemical properties</td>
<td>Increase in non-structural carbohydrates at elevated CO₂. Increase in crude protein content of forage with reduced rainfall.</td>
<td>Decrease in crude protein content and digestibility of forage at elevated CO₂ or higher temperatures. No change or decrease in crude protein in regions with more summer rainfall.</td>
</tr>
</tbody>
</table>
Rangeland Responses

- Directional shifts in the composition of vegetation occur most consistently when global change treatments alter water availability.
- Weedy and invasive plant species likely will be favored by CO$_2$ enrichment and other global changes because these species possess traits (rapid growth rate, prolific seed production) that permit a large growth response to CO$_2$.
- CO$_2$ enrichment will likely accelerate the rate of successional change in species composition following overgrazing or other severe disturbances.
- Rangeland vegetation will very likely be influenced more by management practices (land use) than by atmospheric and climatic change.
Pest Response

- Weeds will be favored by increased CO₂
- Increased temperatures will change phenological development of weeds
- Increased spring, winter, and fall temperatures will allow for winter survival and earlier seasonal onset of insects and pathogens
Implications

- Temperature increases will alter phenological development of crops, increase potential sensitivity to temperature extremes in fruit crops.
- Temperature increases will affect reproduction because of sensitivity of pollen to extreme temperatures.
- Overall impact will be to decrease crop yield and forage quality.
- Temperature increases will negatively impact animal production and reproduction.
Implications

- Increasing CO$_2$ will positively impact plant growth and ultimately yield.
- Increasing CO$_2$ will reduce crop water use which will be an advantage under water limitations.
- Increasing CO$_2$ will offset some of the negative impacts of increasing temperature.
Management Changes

- Producers can adapt to climate changes by altering crop management practices, e.g., planting date, crop selection, nutrient management.
- Producers can adapt to climate changes in livestock through changes in management practices that reduce exposure to thermal stress.