

Agricultural Outlook Forum  
U.S. Department of Agriculture

February 21-22, 2008

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

Jerry L. Hatfield

# How will Climate Change Affect Agriculture?

Impacts over the next 10-30 years

# Contact Information

Jerry L. Hatfield  
Laboratory Director  
National Soil Tilth Laboratory  
2110 University Blvd  
Ames, Iowa 50011  
515-294-5723  
515-294-8125 (fax)  
[jerry.hatfield@ars.usda.gov](mailto:jerry.hatfield@ars.usda.gov)

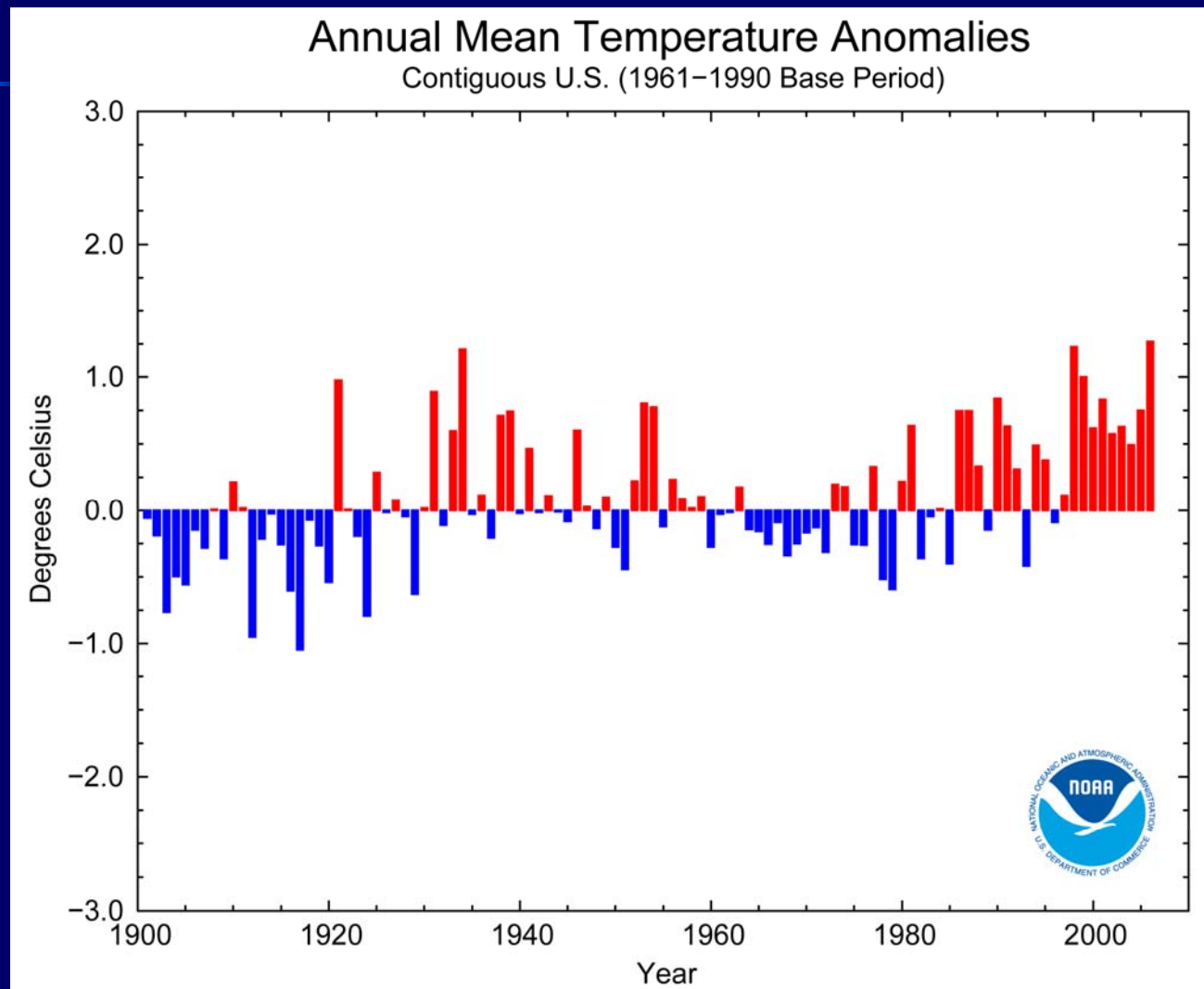
# Contributing Authors

- Ken Boote
- Bruce Kimball
- David Wolfe
- Donald Ort
- Cesar Izaurralde
- Allison Thomson
- Jack Morgan
- Wayne Polley
- Phil Fay
- Terry Mader
- LeRoy Hahn

# Climate Changes

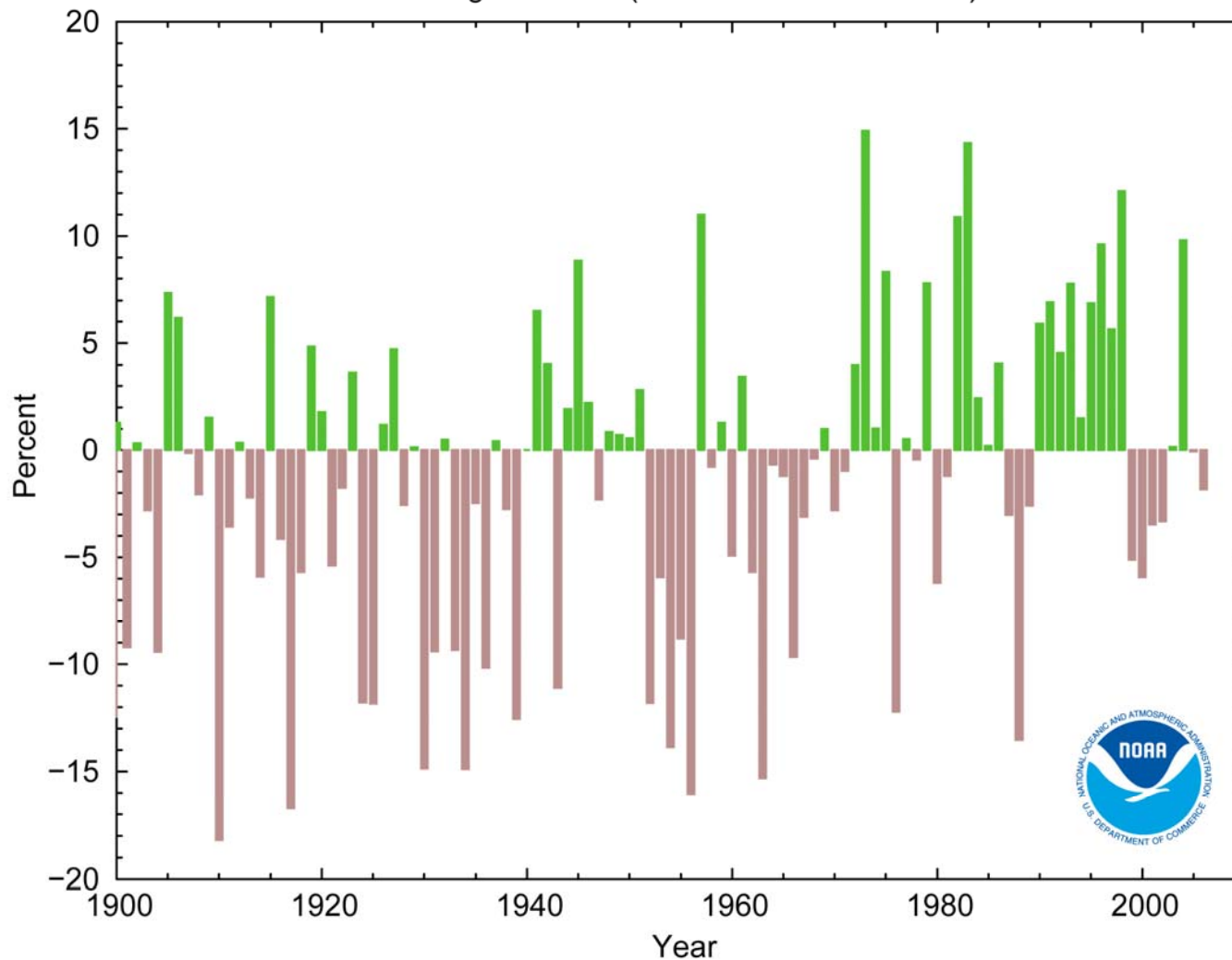
- Increasing temperature of 1.2C (2.2F) over the next 30 years
- Increasing CO<sub>2</sub> of 60 ppm over the next 30 years
- Increasing variability in precipitation
- There will be increasing variation in temperature and precipitation within and among years

# Temperature Changes

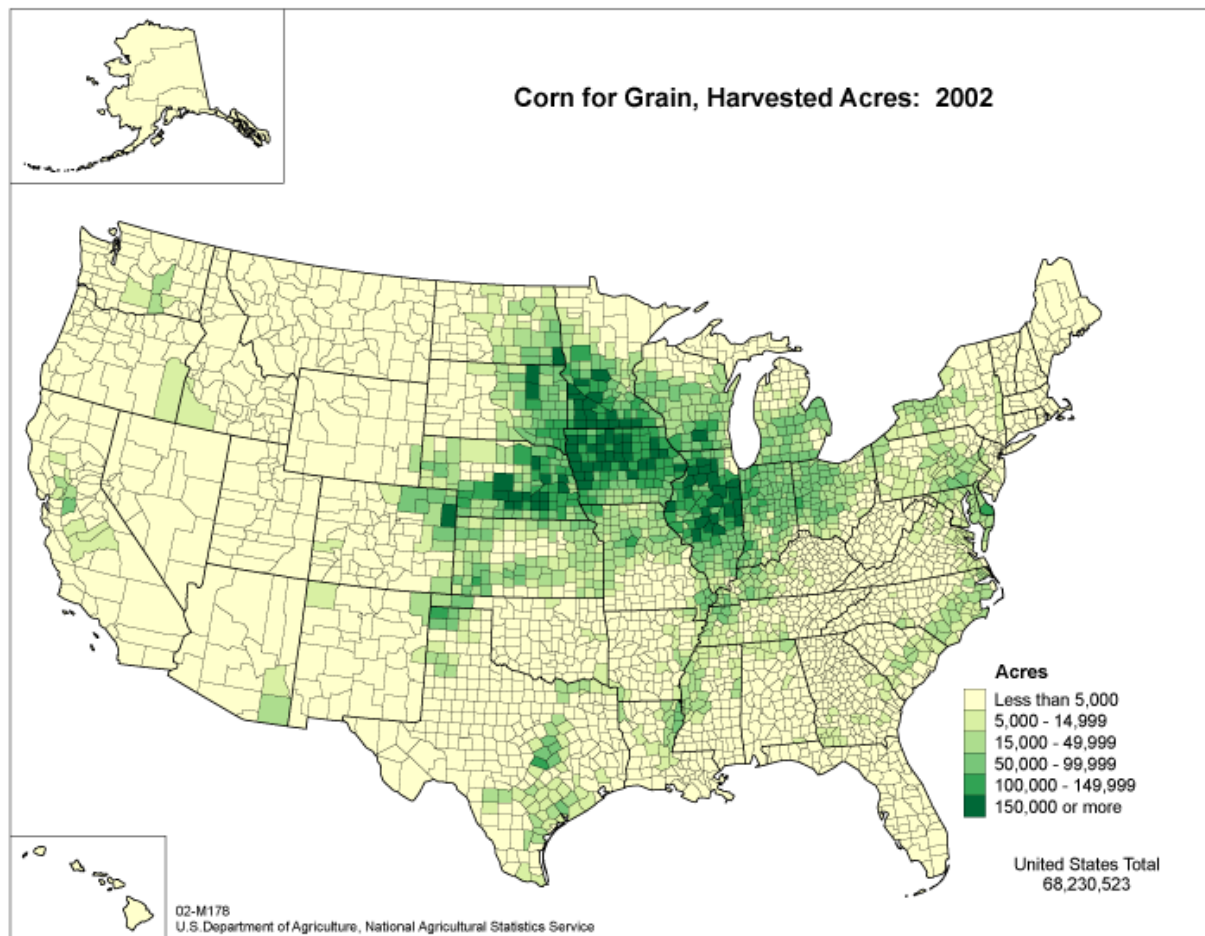


# Precipitation Changes

Annual Precipitation Anomalies  
Contiguous U.S. (1961–1990 Base Period)

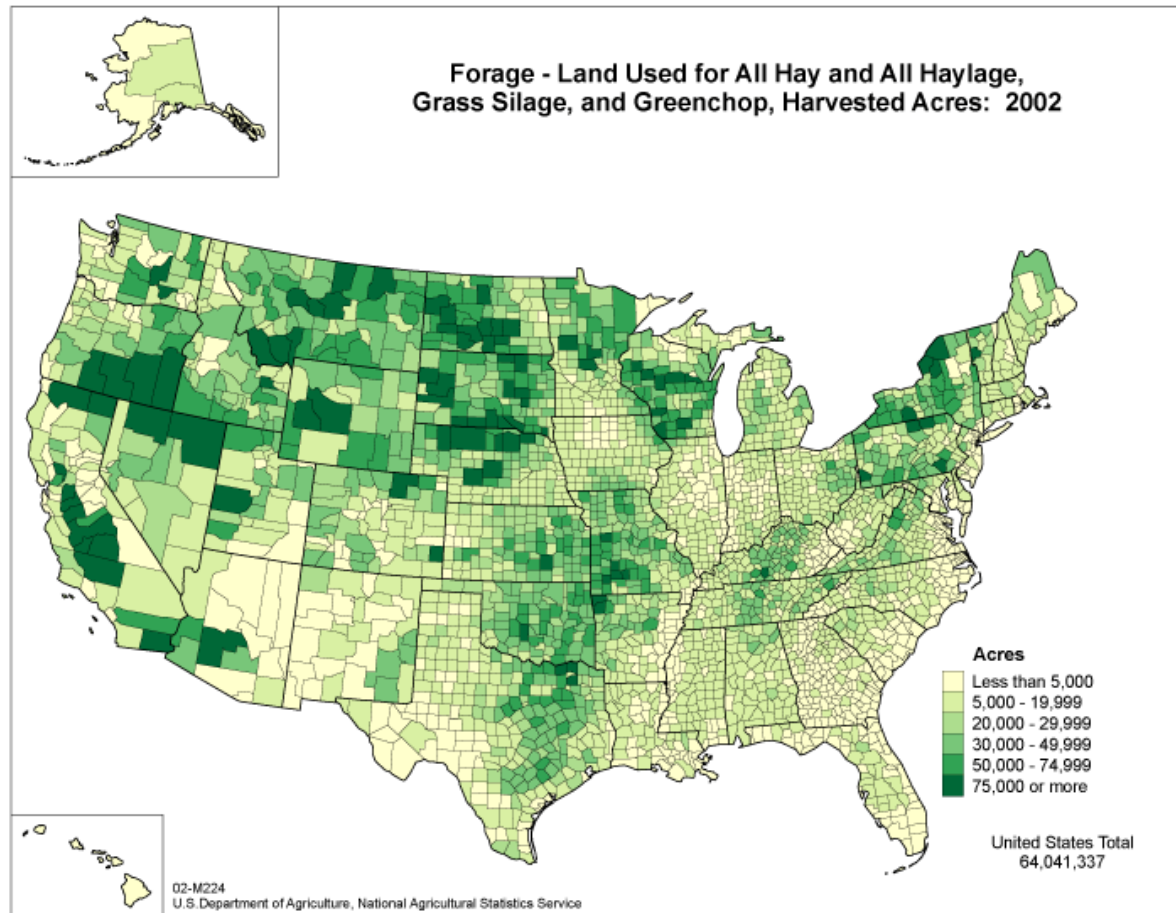


# Corn Production in the US

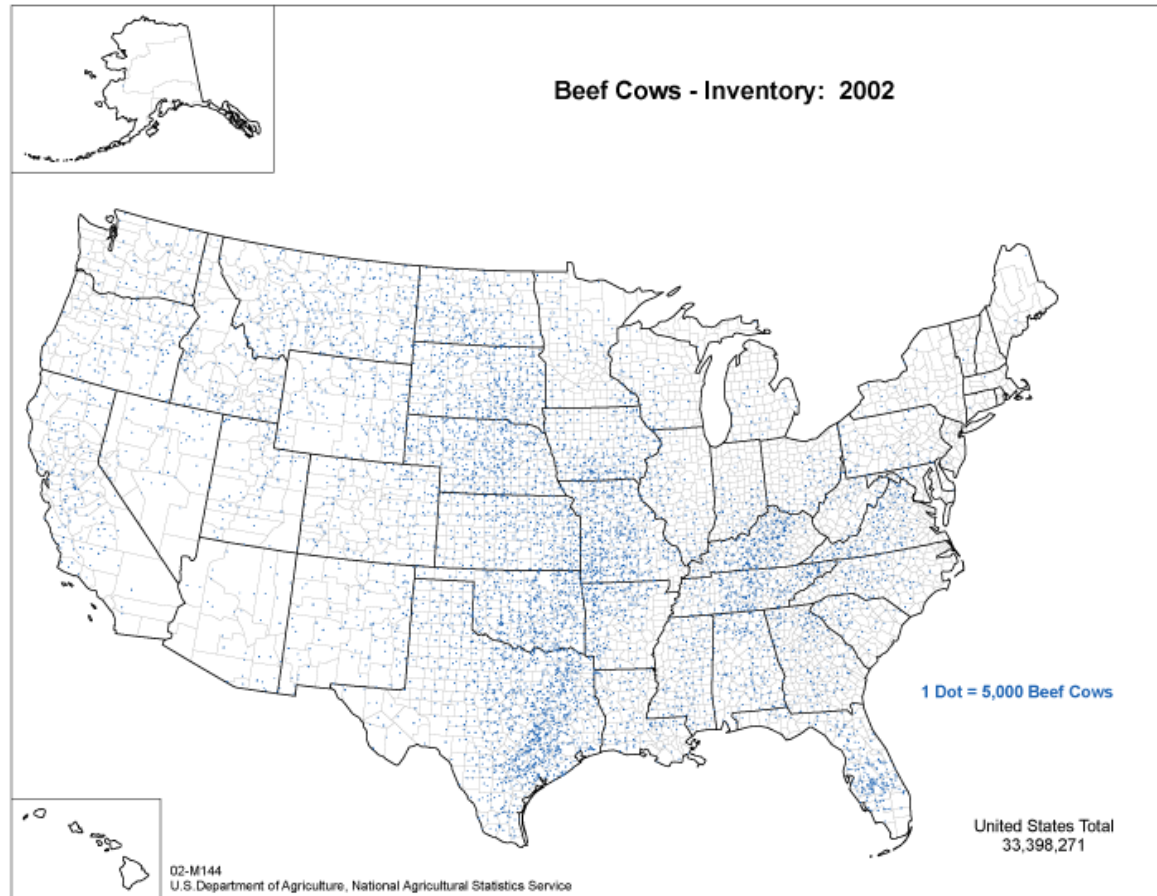




# Forage Production



# Beef Cow Inventory



# 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

Crop	Optimum Temp (C)		Temp Range (C)		Failure Temp (C)
	Veg	Reprod	Veg	Reprod	
Maize	34		18-32	18-22	35
Soybean	30	26	25-37	22-24	39
Wheat	26	26	20-30	15	34
Rice	36	33	33	23-26	35-36
Cotton	37	30	34	25-26	35
Tomato	22	22		22-25	30

# Temperature

Crop	Temp Range (C)	
	Veg	Reprod
Watermelon	18-35	25-27
Cucumber	12-30	20-25
Sweet Corn	12-30	20-25
Onion	7-30	20-25
Potato	5-25	16-25
Broccoli	5-25	16-18

# 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

Crop	Yield Change
Maize	-4.0%
Soybean-Midwest	+2.5%
Soybean-South	-3.5%
Wheat	-6.7%
Rice	-12.0%
Sorghum	-9.4%
Cotton	-5.7%
Peanut	-5.4%
Bean	-8.6%



# Forages

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

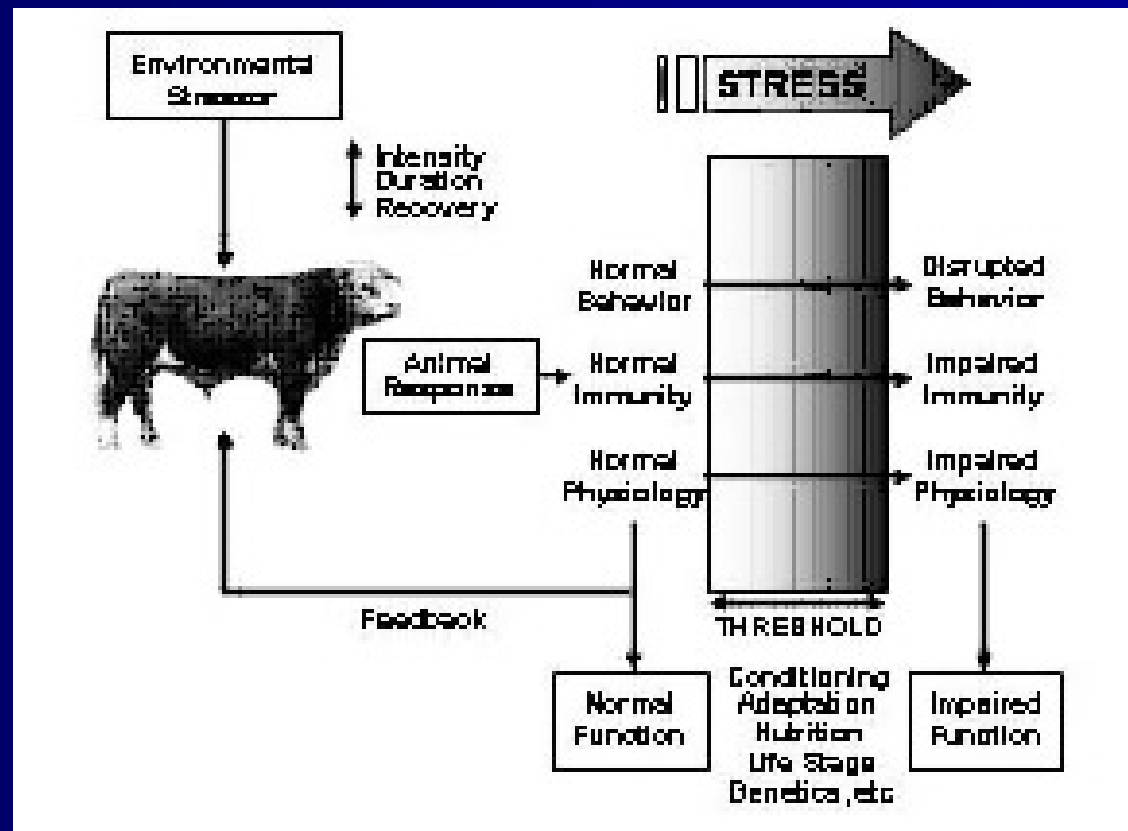
# Fruits and Nuts

- 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

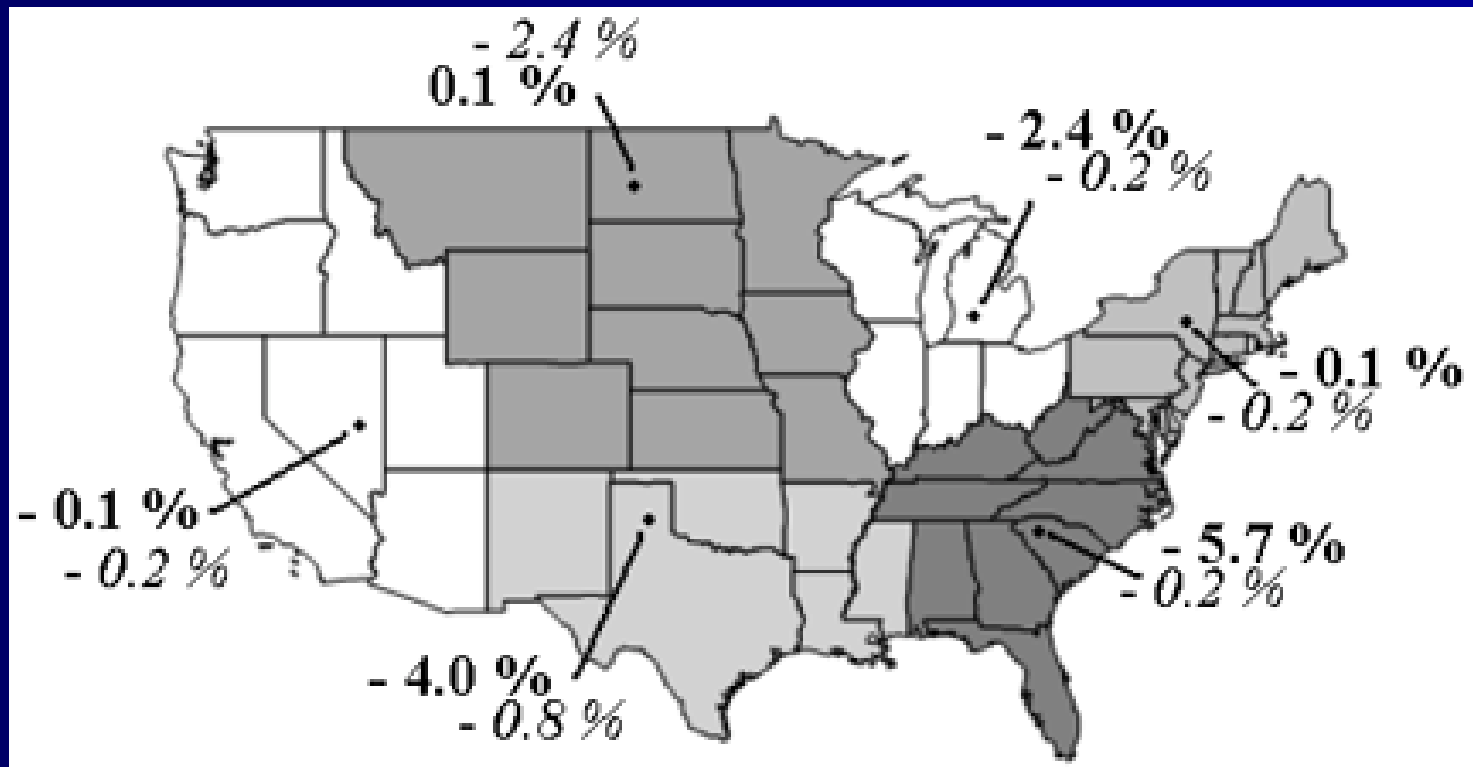
- Optimum temperature is a very narrow range (thermoneutral zone) in which animal does not need to alter behavior or physiological function to maintain core temperature
- Responses include panting, shivering, reduced feed intake, increased (cold) or decreased (warm) metabolic rates
- Any of these responses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

# Temperature Response



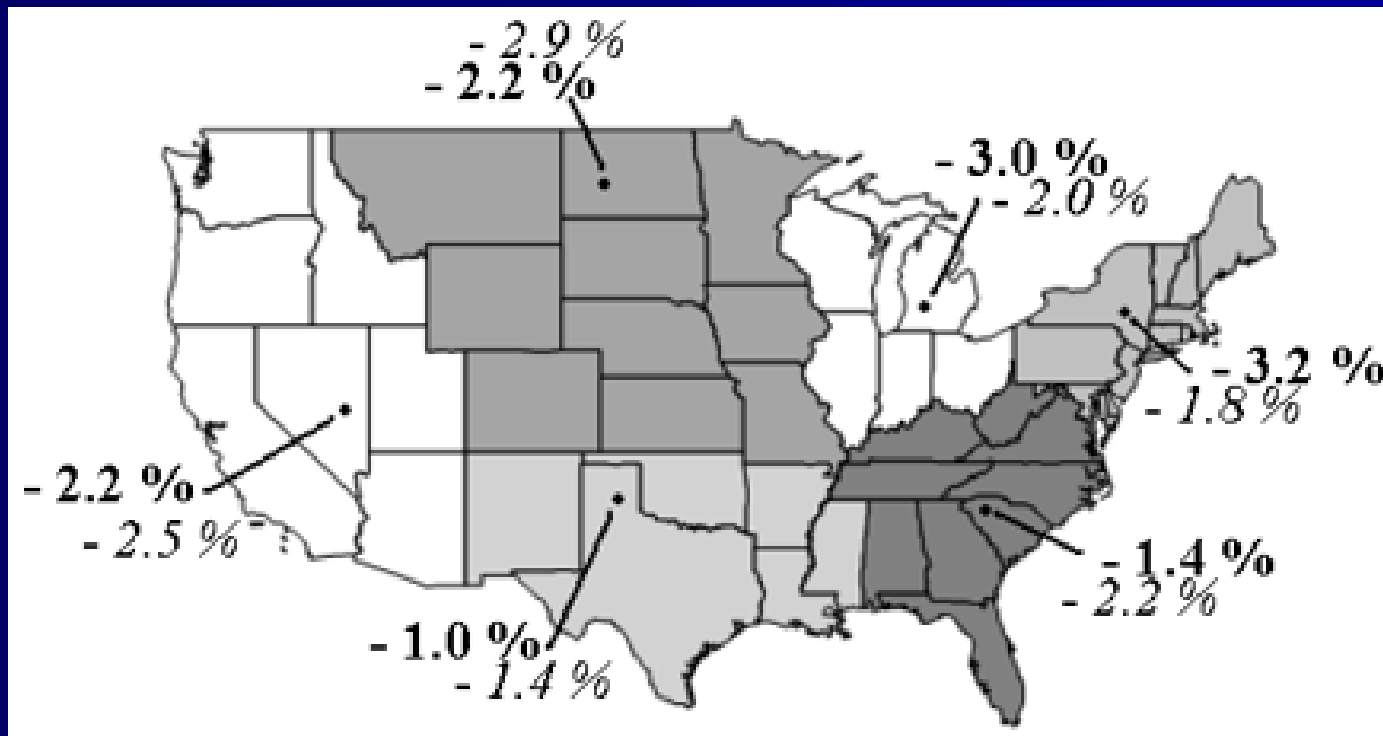


# Impacts on Beef Production



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 23.4C



# Episodic Temperature Events

- High temperature episodes causes 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

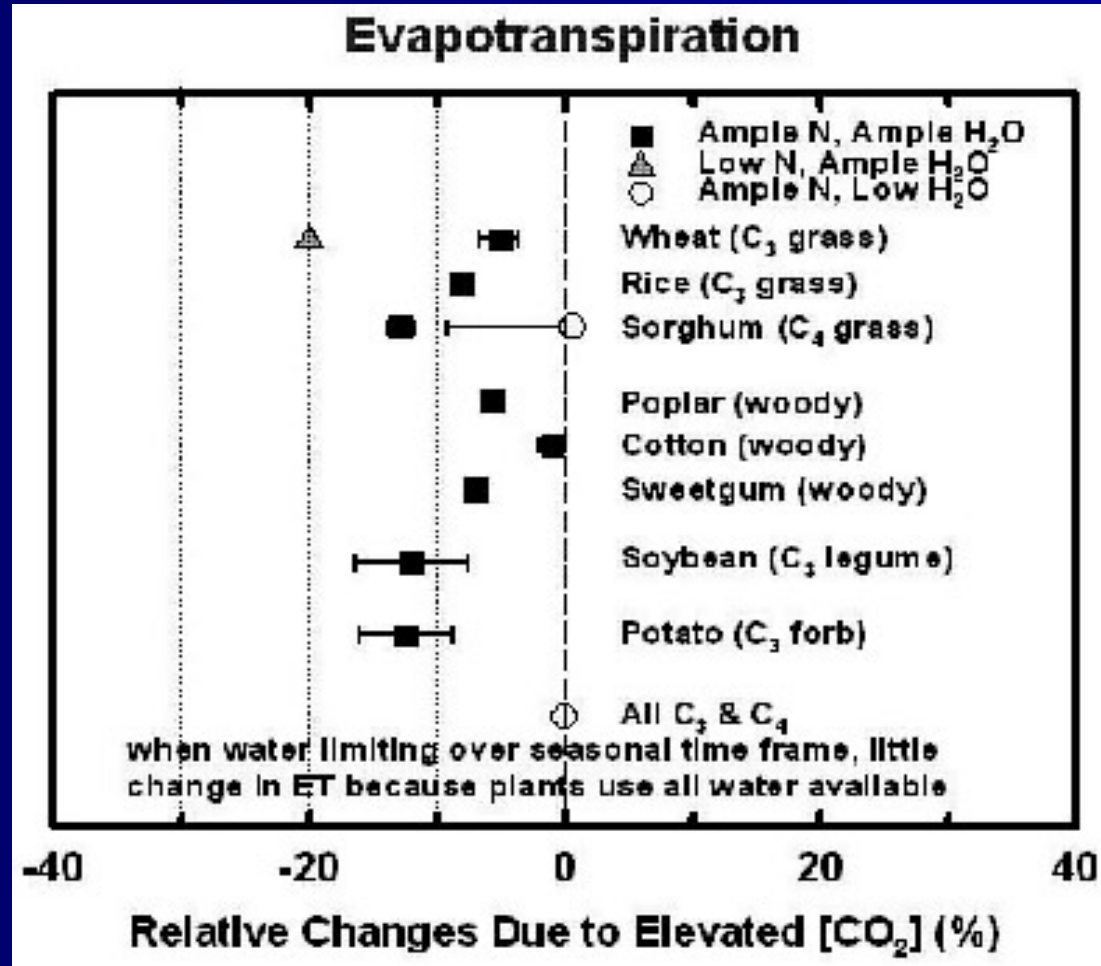
# Carbon Dioxide Responses

- Increasing CO<sub>2</sub> will increase plant growth
- Difference between C3 and C4 plants
- Increasing CO<sub>2</sub> will increase water use efficiency because of increased growth per unit of water transpired

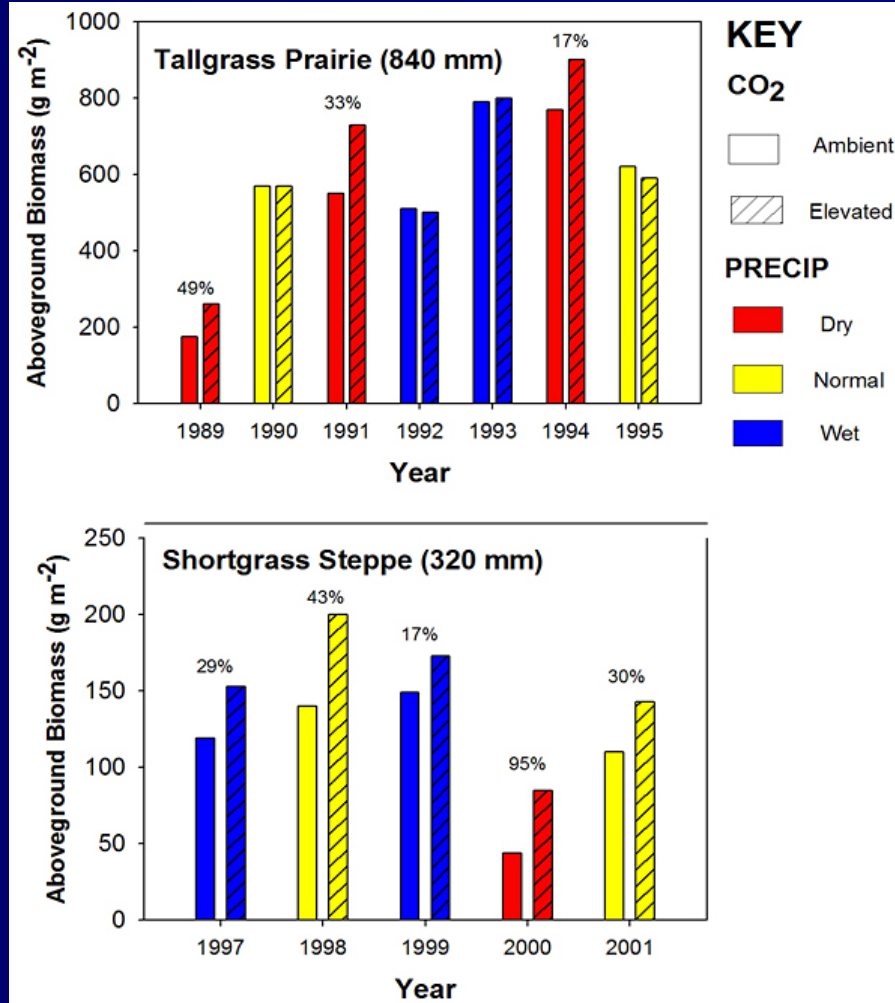
# CO<sub>2</sub> Responses

Crop	Yield Change	ET Change
Corn	+1.0	
Soybean	+7.4	-2.1
Wheat	+6.8	-1.4
Rice	+6.4	-1.7
Sorghum	+1.0	-3.9
Cotton	+9.2	-1.4
Peanut	+6.7	
Bean	+6.1	

# ET effect due to CO<sub>2</sub>



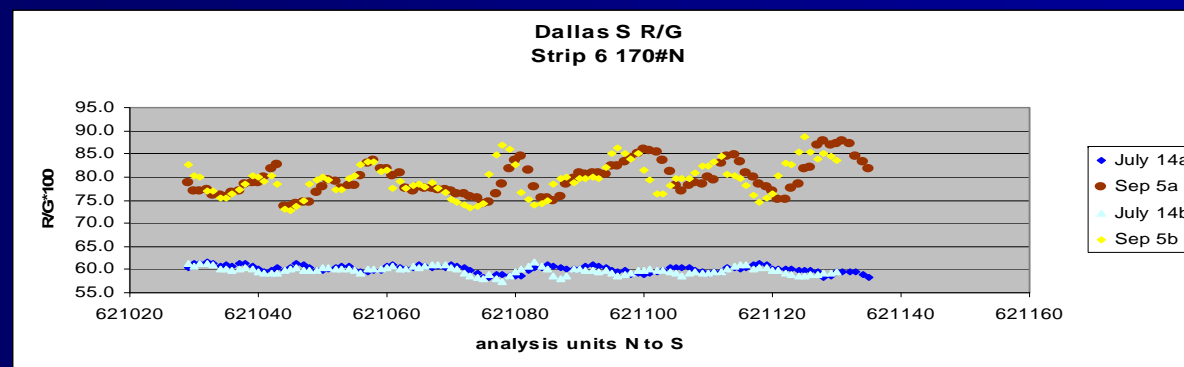
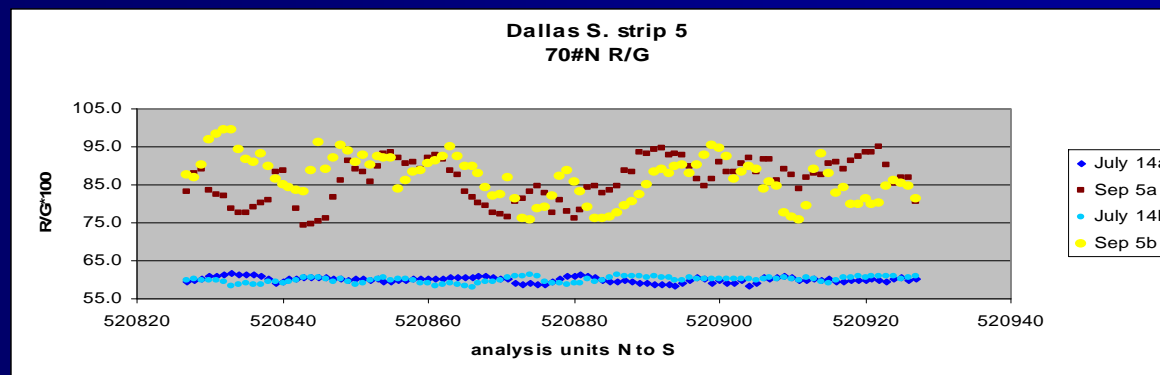
# Rangeland Responses



# Precipitation

- Variable precipitation will increase potential soil deficits
- Decreased soil water availability will offset the positive impacts of CO<sub>2</sub> and exaggerate the effect of increasing temperatures

# Field Scale Variation



# 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

<b>Change</b>	<b>Examples of positive effects on forage quality</b>	<b>Examples of negative effects on forage quality</b>
Life-form distributions	Decrease in proportion of woody shrubs and increase in grasses in areas with increased fire frequency.	Increase in the proportion of woody species because of elevated CO <sub>2</sub> , increases in rainfall event sizes and longer intervals between rainfall events.
Species or functional group distributions	Possible increase in C <sub>3</sub> grasses relative to C <sub>4</sub> grasses at elevated CO <sub>2</sub> .	Increase in the proportion of C <sub>4</sub> grasses relative to C <sub>3</sub> grasses at higher temperatures. Increase in abundance of perennial forb species or perennial grasses of low digestibility at elevated CO <sub>2</sub> . Increase in poisonous or weedy plants.
Plant biochemical properties	Increase in non-structural carbohydrates at elevated CO <sub>2</sub> . Increase in crude protein content of forage with reduced rainfall.	Decrease in crude protein content and digestibility of forage at elevated CO <sub>2</sub> or higher temperatures. No change or decrease in crude protein in regions with more summer rainfall.

# 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<sub>2</sub> enrichment and other global changes because these species possess traits (rapid growth rate, prolific seed production) that permit a large growth response to CO<sub>2</sub>
- CO<sub>2</sub> 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 CO<sub>2</sub>
- 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<sub>2</sub> will positively impact plant growth and ultimately yield
- Increasing CO<sub>2</sub> will reduce crop water use which will be an advantage under water limitations
- Increasing CO<sub>2</sub> 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