Climate and Agriculture

CHALLENGES FOR EFFICIENT PRODUCTION
Diversity of Agriculture

- Annual Crops
- Perennial Crops
- Pasture and Rangeland
- Animals
  - Range
  - Confined
Market Value of Agricultural Products Sold: 2002

United States Total
$200,646,355,000

1 Dot = $20,000,000
Climate Impacts Agriculture

- Temperature
- Carbon dioxide
- Precipitation
- Solar radiation
Climate and Agriculture

- Stress from environmental factors affects productivity and efficiency
- Both climate and weather affect agricultural production systems
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

[Diagram showing the relationship between environmental stressors, animal responses, and threshold with feedback loops involving intensity, duration, and recovery. Key points include normal behavior, normal immunity, normal physiology, disrupted behavior, impaired immunity, impaired physiology, normal function, and impaired function. Factors influencing the threshold include conditioning adaptation, nutrition, stage, genetics, etc.]
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 23.4C
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 the order of millions of dollars.
Challenges

- Manage animal production systems to decrease exposure to extreme temperature events
- Capital investment in facilities to reduce potential thermal stress
- Increased investment in ensuring adequate water for range animals
Crop Production

- Variation among years due to within season weather impacts
- Long-term yield trends reveal the impacts of climate on crop production
World Wheat Yields

World Wheat Production

Production (million metric tons)

Year

Plant Temperature Responses

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

![Diagram showing the relationship between temperature and plant growth rate. The graph indicates a peak at an optimal temperature ($T_{opt}$) with lower growth at temperatures below ($T_{min}$) and above ($T_{max}$) the optimal range.]
Temperature Responses

Corn
- Vegetative Optimum Range: 77-100 °F
- Reproductive development
  Optimum Range: 62-72°F
  Failure: 95°F

Soybean
- Vegetative Optimum Range: 77-97°F
- Reproductive development
  Optimum Range: 72-75°F
  Failure: 102°F
Temperature Impacts

- Warming temperatures causes faster plant development (vegetative and reproductive)
- Faster development doesn’t equate to increased grain yield
- Warmer nighttime temperatures increase the respiration rate and reduce growth or yield
Current Mega-climate regimes

Future (2050) mega-climate regimes

Move from a favorable to unfavorable climate for wheat

Ortiz et al. Agric Ecosys & Environ. 2008. 126:46-58
Water and Crops

- Majority of crops are produced in rainfed environments and amount of water available to a plant depends upon frequency of precipitation and water holding capacity of the soil.
- Increased variability in precipitation will further increase the risks to crop production.
Water Impacts

The greater the transpiration rate, the larger the yield.

The slope of the line is water use efficiency.
Water Use Efficiency

Yield $= 3022 + 27.9 \ \text{Water Use} \ r^2 = 0.63$

- 150 kg ha$^{-1}$
- 100 kg ha$^{-1}$
- 200 kg ha$^{-1}$
- 50 kg ha$^{-1}$
Water Use Between Soils

Corn Water Use 2000

- Clarion Spring N (100 kg/ha)
- Webster Spring N (100 kg/ha)
- Clarion Fall N (200 kg/ha)
- Webster Fall N (200 kg/ha)
Annual Precipitation

Walnut Creek Precipitation

Cumulative Precipitation (mm)

Day of Year

1997
1998
1999
2000
Variation in Precipitation

Total Rainfall (6/1/02-8/19/02) (cm)
Dallas South Yields

Data comparisons from last two strips

North

Dallas S R/G
Strip 6 170#N

R/G*100

analysis units N to S

July 14a
Sep 5a
July 14b
Sep 5b
Water Use Efficiency

![Graph showing water use efficiency for different hybrids in 2004. The x-axis represents different hybrids, and the y-axis represents precipitation use efficiency. There are data points for Spring Strip and Fall Chisel.]
Soil Water Availability

Data Points

- Sand, AWC = 3.8 + 2.2 OM
- Silt Loam, AWC = 9.2 + 3.7 OM
- Silty clay loam, AWC = 6.3 + 2.8 OM

Hudson, 1994
Managing Soil Water

- Increasing water supply to the crop throughout the growing season will be critical to long-term efficient production.
- Improve the ability of the soil to retain precipitation and supply to growing crop will be the difference in crop yields.
Carbon Dioxide Responses

- Increasing CO₂ will increase plant growth
- Difference between C3 and C4 plants
- Increasing CO₂ will increase water use efficiency because of increased growth per unit of water transpired
CO₂ Effects on Weeds

Ambient CO₂  

Future CO₂ (+300 ppm)

Increasing CO₂ reduces herbicide efficacy.

e.g. Ziska et al. Weed Science 2004
Crop Production

- Increasing temperature will require a change in planting dates or tolerant varieties to avoid exposure to high temperatures.
- Need to increase the soil water holding capacity to increase available water to the developing crop either by improving organic matter or reducing evaporation from soil.
- Changes in weed response under increasing CO\textsubscript{2} will present additional challenges.
Impacts on Rangeland and Pastureland

- Variability of precipitation will impact growth of pastures and rangeland
- Increasing CO$_2$ will impact forage quality and species composition in rangelands
- Interactions of grazing management, climate change, and species composition will impact the long-term use and sustainability
Implications for Agricultural Production

- Increased impact of climate that will tax our abilities to efficiently produce crops
- Develop systems level research to understand the impact on farming systems and the interactions among genetics, environment, and production systems.