Carbon, Climate, and Energy

CRITICAL CONNECTIONS FOR AGRICULTURE
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The Problem

The challenge to produce enough food will be greater over the next 50 years than in all human history.
Worldwide Land Area

Worldwide Land Availability

Year
1960 1980 2000 2020 2040

Land Area per Capita (ha)
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45
Problem

Production deficit to meet food needs for population increase

Translates to a water deficit since water use curve behaves as
Water Requirements

Water deficit need 120 mm more water to grow 300 bu corn
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
Our soil resources are being taxed more with the rapidly increasing population, as a result, soil degradation will take place much faster than ever before.

Carbon is Critical!
Earthworms, insects and rodents are the most visible components of the “living soil” team. They work in tandem with soil microorganisms and fungi to contribute to aeration and nutrient cycling as part of a “soil factory” team effort.
CONSERVATION-TILLED farm fields consume ~4.6 tons of organic matter under the surface of every acre each year.

“That microbial action is the equivalent of grazing two African elephants per acre,”

Source: Jerry Hatfield, the director of USDA’s National Laboratory for Agriculture and the Environment in Ames, Iowa.
The "living soil", a biological system.

Mammals - gophers, moles, mice, groundhogs
Earthworms - night crawlers, garden worms
Insects and mollusks - ants, beetles, centipedes, snails, slugs
Microfauna - nematodes, protozoa, rotifers≈
Microflora - fungi, yeast, molds, mychorhiza
Actinomycetes - smaller than fungi, act like bacteria
Bacteria - autotrophs, heterotrophs, rhizobia, nitrobacter
Algae - green, blue-green

Earthworms, insects and rodents are "nature’s plow" and the most visible components of the "living soil" team. They work in tandem with other soil fauna, soil microorganisms and fungi to contribute to aeration and nutrient cycling as part of a “soil factory” team effort.
Tillage creates a battle field for the soil biology that is trying to help.
Crop residue benefits

Simple crop residue on the surface

Feeding the complex soil biology working hard for you below the surface.
Changing Climate

- Temperature
- Precipitation
- Carbon dioxide
Carbon Dioxide Increases

The graph illustrates the increase in concentrations of Carbon Dioxide (CO₂), Methane (CH₄), and Nitrous Oxide (N₂O) over time. The concentrations are measured in parts per billion (ppb) and are shown on the Y-axis. The X-axis represents the years, with a significant increase in the last century. The graph clearly shows the rise in atmospheric concentrations of these greenhouse gases, indicating a significant environmental concern.
Temperature Changes

Linear trend of Surface Air Temperature 1901-2008

Source: UDel.
Nighttime Temperatures
Nighttime Temperatures (Ames)

<table>
<thead>
<tr>
<th>Year</th>
<th>Temperature (F)</th>
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<tr>
<td>1880</td>
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<tr>
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<td>1980</td>
<td>64</td>
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<td>2000</td>
<td>66</td>
</tr>
</tbody>
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Ames Minimum Temperature - Summer

- Mean Summer Temp
- Summer Temp (June-Aug)
Summer Temperature Change

MultiModel B1 2040s

MultiModel B1 2080s

MultiModel A2 2040s

MultiModel A2 2080s

Legend:
-5 -4 -3 -2 -1 0 1 2 3 4 5
Change in Dry Periods and Hot Nights

Change in Maximum Number of Consecutive Dry Days

Change in number of hot nights
Precipitation Changes

Linear trend of Annual Precipitation 1901-2006

trend in %

Source: UDel.
Projected Change in N. American Precipitation by 2080-2090
Iowa Statewide Spring Precipitation Totals

Precipitation (inches) vs Year from 1890 to 2010.
The increase in spring precipitation has decreased the number of workable field days in April through mid-May across Iowa by 3.5 inches in 1995 to 2010 compared to 1979-1994.
Des Moines Precipitation
Days per Year with More than 1.25 inches

Years having more than 8 days
2

350% Increase

2010 through Sept 27
7

3.7

41% Increase

5.2
Soil Erosion

Degrading the soil resource decreases the water holding capacity

Hudson, 1994
Regional Differences in Spring Precipitation

[Map showing regional differences in spring precipitation percentages.]
“Parallel Hockey Sticks”

From Intergovernmental Panel on Climate Change
Carbon          Water          Nitrogen

Key Processes
Photosynthesis               Precipitation            N Fixation
Respiration                        Evaporation             Mineralization
Org Matter decomp      Infiltration
Plant decomposition     Runoff
Plant decomposition

Percolation

Cycles interact over time and space with different rates
Energy Balance System
Soils of two Fields In
Walnut Creek Watershed
Story County, Iowa

Plots

Scale 1:7198

Prepared By: Wolfgang Osiertich
USDA-ARS
National Soil Tilth Lab
Ames, IA.
Study Site

Full energy balance and plant growth measurements

Coupled water and carbon dioxide measurements

Measurements throughout the season
Corn Yield
Nitrogen Response
Duration of Photosynthetic Capacity

Cumulative PSRI x PAR

Yield (bu/ac)

190x10^3  200x10^3  210x10^3  220x10^3  230x10^3  240x10^3  250x10^3

40
60
80
100
120
140
160
180

Cumulative PSRI x PAR
Light Use Efficiency

![Graph showing Light Use Efficiency for different hybrids and planting methods. The x-axis represents the hybrid numbers, and the y-axis represents the light use efficiency. The graph compares Spring Strip and Fall Chisel planting methods for the year 2004.]
The majority of the yield losses due to the weather are short-term stresses.
Crop Yield Variation
Current State of Agricultural Soils

Soil Organic Matter Content

Soil Water Holding Capacity

Soil Organic Matter

Time since cultivation
Figure 1. Fuel use as related to tillage intensity (data from Archer and Reicosky 2009).
CO₂ & H₂O loss from Low vs High Disturbance Drills

- CO₂ loss (gCO₂/m²/h)
  - None: 0.38
  - Low: 0.35
  - High: 3.01

- Evaporation (mm/h)
  - None: 0.17
  - Low: 0.35
  - High: 0.70

Disturbance Type:
- None
- Low
- High
Soil Water Use Rates

Corn Water Use 2000

Day of Year

Water Use (mm)

Clarion Spring N (100 kg/ha)
Webster Spring N (100 kg/ha)
Clarion Fall N (200 kg/ha)
Webster Fall N (200 kg/ha)
Soil Water Availability

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Hudson, 1994
Virtually all the benefits of no till come from the continuous “protective blanket” of crop residue or biomass. and not from the lack of soil disturbance by tillage.

Credit: Rolf Derpsch
“Passive protective blanket”

“Active protective blanket”
Agricultural systems represent the interaction of carbon and energy dynamics.

Sustainable systems will have to be able to cope with a rapidly changing climate.

One key to resilient cropping systems is to improve the soil for both erosion protection along with water storage capacity.

Managing our soils as part of the cropping system will increase the efficiency of water, light, and nutrient use.