What does our regional ag system look like?
Are we in for a Crisis?

The End of Oil
On the Edge of a Perilous New World
Paul Roberts

The End of Food
Paul Roberts

Diet for a Hot Planet
The Climate Crisis at the End of Your Fork and What You Can Do About It
Anna Lappé

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For anyone concerned about the future of food, this is an indispensable book.
—Michael Pollan

Foreword by Bill McKibben
Climate Change
US Corn Production Under Climate Change

WACCIA Project: Projected Changed in Temperature for PNW

* Compared with 1970-1999 average
Projected change in frost-free period (days)
Projected Changes in Annual Precipitation

- Changes in annual precipitation averaged over all models are small but some models show large seasonal changes, especially toward wetter autumns and winters and drier summers.

* Compared with 1970-1999 average
What about Atmospheric CO$_2$ increase?

IPCC Projections

Atmospheric CO$_2$ concentration (µmol mol$^{-1}$) vs. Relative change

- Maize (Landriano)
- Wheat (Landriano)
- Maize (Aleppo)
- Wheat (Aleppo)

Relative change of Radiation-use efficiency for wheat and maize simulated with the CTP model (Stockle and Kemanian, 2009)
WACCI A results

Winter Wheat Pullman (6.2 Mg/ha)

Spring Wheat Pullman (4.4 Mg/ha)

Apples Sunnyside (61 Mg/ha)

Potatoes Othello (81 Mg/ha)
Example of climate change on inland PNW

Agroecological Zones

Legend
- Douglas AEZ boundaries
- Counties
- 2050 Modeled Data
- Unclassified
- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 5
- Zone 6
- > 1000 GDD

2050
Crop Model - Apple Yields

- Yields decline from historic by 20% to 25% (2020s) and 40% to 50% (2080s)

Yakima Basin Case Study, Vano, et.al. 2009
**Table ES-1.** Forecast increases in demands by sector from 2010 to 2030 in eastern Washington (Water Resource Inventory Areas 29-62). Demands for out-of-stream uses are presented as diversion demands.

<table>
<thead>
<tr>
<th>Demand Type</th>
<th>Estimated Volume (ac-ft)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030 New Irrigation Demand</td>
<td>170,000</td>
<td>WSU Integrated Model</td>
</tr>
<tr>
<td>2030 New Municipal and Domestic Demand (including municipally-supplied commercial)</td>
<td>108,500</td>
<td>WSU Integrated Model</td>
</tr>
<tr>
<td>Unmet Columbia River Instream Flows</td>
<td>13,400,000</td>
<td>Ecology data, McNary Dam, 2001 drought year</td>
</tr>
<tr>
<td>Unmet Tributary Instream Flows</td>
<td>500,000</td>
<td>Ecology data, tributaries with adopted instream flows, 2001 drought year</td>
</tr>
<tr>
<td>2030 New Hydropower Demand</td>
<td>0</td>
<td>WSU Surveys and Planning Forecast Review</td>
</tr>
<tr>
<td>Alternate Supply for Odessa</td>
<td>164,000</td>
<td>Odessa Draft EIS (October 2010)</td>
</tr>
<tr>
<td>Yakima Basin Water Supply (pro-ratales, municipal/domestic and fish)</td>
<td>450,000</td>
<td>Yakima Integrated Water Resource Management Plan (April 2011)</td>
</tr>
<tr>
<td>Unmet Columbia River Interruptibles</td>
<td>40,000 to 310,000</td>
<td>Ecology Water Right Database (depending on drought year conditions)</td>
</tr>
</tbody>
</table>
## Columbia River Forecast

Table ES-2. Top of crop agricultural demands under the baseline economic scenario (medium domestic economic growth and medium growth in international trade), excluding conveyance losses, in the Columbia River Basin in the historical and 2030 forecast period. Estimates are presented for average years, with range in parentheses representing dry (20th percentile) and wet (80th percentile) years.

<table>
<thead>
<tr>
<th></th>
<th>Historical (1977-2006)</th>
<th>2030 Forecast</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>million ac-ft per year</td>
<td>million ac-ft per year</td>
<td></td>
</tr>
<tr>
<td>Entire Columbia River Basin</td>
<td>13.3 (12.6-13.9)</td>
<td>13.6 (13.1-14.1)</td>
<td>2%</td>
</tr>
<tr>
<td>Washington Portion of the</td>
<td>6.3 (6.0-6.5)</td>
<td>6.5 (6.2-6.6)</td>
<td>2%</td>
</tr>
<tr>
<td>Columbia River Basin</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 8. Historical (1977-2006) and 2030 forecast regulated surface water supplies on the Snake and Columbia Rivers upstream of the point where they enter Washington State for dry (20th percentile, top), average (middle), and wet (80th percentile, bottom) flow conditions. The spread of 2030 flow conditions is due to the range of climate change scenarios considered.
Figure 15. Historical (1977-2006) surface water supply at Bonneville, McNary, and Priest Rapids dams for low (20th percentile), average, and high (80th percentile) flow conditions. Also shown are the Washington State instream flow (ISF) and federal BiOp flow targets.

Figure 16. Forecast 2030 surface water supply at Bonneville, McNary, and Priest Rapids dams for low (20th percentile), average, and high (80th percentile) flow conditions. Also shown are the Washington State instream flow (State ISF) and federal BiOp flow targets.
Using Decision Aids for “Smart” Adaptation

Generalized Life History of Codling Moth in Washington

2 complete generations

Partial 3rd generation

Bloom

Mid August

Control period

Control period

May June July Aug. Sept.

DD from biofix

Figure 2: Codling moth life history as described by degree-day model
Climate Change will . . .

“add another layer of complexity and uncertainty onto a system [agriculture] that is already exceedingly difficult to manage on a sustainable basis.”

--Coakley, et.al. 1999
Climate Friendly Farming™

Reducing our ag carbon footprint is a strategy for both mitigation AND adaptation.
How much does food contribute to GHGs?
(How and what you inventory actually matters . . .)
### Direct GHG Emissions from US Agriculture Production

#### Table 6-1: Emissions from Agriculture (Tg CO₂ Eq.)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>CH₄ Enteric Fermen</td>
<td>194.0</td>
<td>140.8</td>
<td>45.0</td>
<td>7.2</td>
<td>1.0</td>
<td>233.5</td>
</tr>
<tr>
<td>Rice Cultivation</td>
<td>215.9</td>
<td>17.1</td>
<td>0.5</td>
<td></td>
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<td></td>
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<tr>
<td>Field Burning Agricultural</td>
<td></td>
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<tr>
<td>N₂O Agricultural Management</td>
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<tr>
<td>Manure Management</td>
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<tr>
<td>Manure Management</td>
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<tr>
<td>Field Burning Agricultural</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
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<td></td>
<td>427.5</td>
</tr>
</tbody>
</table>

#### Diagram: Ag's % of Total Direct Emissions (US)

- **Total**: 10%
- **CO₂**: 0%
- **CH₄**: 70%
- **N₂O**: 30%
- **Manure**: 0%

US EPA (2010)
Historical Carbon Loss from Soils

Difference in total soil organic C between native and cultivated soils by soil type near Pullman, WA.

Portions of these data were published by Purakayastha et al. (2008).
Simulated average annual change in C over the first 12 years after converting from CT to either RT. Carbon values include the top 30 cm of soil and residue C. Changes in carbon were simulated with a low SOC oxidation rate (lower boundary, part A) and a high SOC oxidation rate (upper boundary, part B).
Annual N$_2$O emissions, averaged over 30 years, either simulated by CropSyst or calculated according to the IPCC equation (1.25% +/- 1% of adjusted applied nitrogen), for various tillage intensities and crop rotations at four locations in eastern Washington State.
Partial Life Cycle Assessment of Common PNW Wheat Production Systems

<table>
<thead>
<tr>
<th>LCA Scenario No.</th>
<th>Rotation (Rainfall zone) - Tillage</th>
<th>Annual global warming potential per acre for wheat-based rotations under different tillage, precipitation zones, and crop rotations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>WW-SB-SW (high) - CT</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>WW-SB-SW (high) - RT</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>WW-SB-SW (medium) - NT</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>WW-SB-FY (medium) - CT</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>WW-SB-FY (low) - CT</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>WW-FY (low) - CT</td>
<td></td>
</tr>
</tbody>
</table>
**Is Organic Farming more “climate-friendly”?**

<table>
<thead>
<tr>
<th>Cropping Method</th>
<th>Global Warming Potential (lbs CO₂ equiv / acre / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>1014.6</td>
</tr>
<tr>
<td>No-till</td>
<td>124.6</td>
</tr>
<tr>
<td>Organic</td>
<td>364.9</td>
</tr>
<tr>
<td>Early Successional</td>
<td>-1877.9</td>
</tr>
</tbody>
</table>

Kellogg Biological Station (Michigan) LTER, [http://lter.kbs.msu.edu/](http://lter.kbs.msu.edu/)
Is Organic Farming more “climate-friendly”?


- Fossil energy reduced by 33 – 50% over conventional
- Organic no-till reduces fossil fuel by 75%

<table>
<thead>
<tr>
<th></th>
<th>CONV</th>
<th>LEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize yield (kg/ha)</td>
<td>7170</td>
<td>7100</td>
</tr>
<tr>
<td>Cum. NPP (MT/ha)</td>
<td>75 b</td>
<td>68 a</td>
</tr>
<tr>
<td>Plant residues returned</td>
<td>43 b</td>
<td>39 a</td>
</tr>
<tr>
<td>Soil C change (MT/ha)</td>
<td>2.2 ns</td>
<td>6.6*</td>
</tr>
</tbody>
</table>

**Energy input (Mil kcal/ha)**
- corn: 5.2 vs. 3.6
- soybean: 2.1 vs. 2.3

Soil C storage in organic ~70 gal DFE/ha/yr

(Drinkwater et al., 1998; Pimentel et al., 2005)
Growing / Recycling N on site • Reducing tillage • Increasing C inputs (site limits) • Improved H2O Management • Perennials • Manure Management

Can we take advantage of Climate Friendly Farming Practices in Whatcom?
Importance of “organic” amendments for mitigating GHG, sequestering C?

CropSyst Simulation of Manure Application With and Without Anaerobic Digestion (AD)

Initial soil organic matter (%)
Smart Carbon and Nutrients
The next step in Climate Friendly Farming

Removing 20% of total C annually ~10% of Washington’s Net CO₂

176,000 MT of synthetic N fertilizer inputs in 2001

At least 16.9 Million Dry Tons Biomass in Washington
Current Generation Soil Amendments

Composts, biosolids, manures, etc.: Recovered C, N, other nutrients, microbial activity, etc.

Costs of Production

- Winter Wheat ~$300 – 400 / acre
- Winter Canola ~$200 – 250 / acre
  N fertilizer up to 40% of cost
Next Generation Soil Amendments

Critical Characteristics for Next Generation Organic Soil Amendments

• Consistency and reliability
• Predictability
• Precision

Cost / Value of Production

- Potatoes - ~$3,000+ / acre
- Spinach Seed - $3,000 / acre
- Sweet Cherries - ~$9,500 / acre
- Greenhouse / Nursery -- $600k – $800k / acre

Brassica Seed Meal
Biochar
Bio Fertilizers
Digested Dairy Solids
## Potential for AD to reduce GHG

(Hint: Single biggest ag opportunity)

Table 11.1: Summary of greenhouse gas savings from AD co-digestion with nutrient recovery (assumed 70,000 cows, across 40 AD projects, each co-digesting at 20% v/v)

<table>
<thead>
<tr>
<th></th>
<th>Total MMt CO$_2$ e/yr</th>
<th>Total Mt CO$_2$ e/cow yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD methane capture</td>
<td>0.342</td>
<td>4.89</td>
</tr>
<tr>
<td>Co-digestion methane</td>
<td>0.611</td>
<td>8.73</td>
</tr>
<tr>
<td>Electrical offset</td>
<td>0.114</td>
<td>1.63</td>
</tr>
<tr>
<td>Peat Replacement using separated fiber</td>
<td>0.019</td>
<td>0.27</td>
</tr>
<tr>
<td>Bio-phosphorous from P-solids recovery</td>
<td>0.0031</td>
<td>0.04</td>
</tr>
<tr>
<td>Bio-nitrogen from ammonia stripping</td>
<td>0.014</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.103</strong></td>
<td><strong>15.76</strong></td>
</tr>
</tbody>
</table>

*Plus additional GHG mitigation from potential reductions in N$_2$O emissions or increases in soil carbon.*
Need updated chart from Craig's Presentation
Chad Kruger, 10/10/2011
Recovering C, N, and P from farm and food wastes

From largest 135 WA Dairies (167k cows, 50k heifers):

**Nitrogen recovered**
~ 20% of state’s on-farm demand for N

**Phosphorous recovered**
~27% of state’s on-farm demand for P
Compressed biomethane as a transportation fuel

1.79 - 3.75 MT CO2e / cow (manure, co-digestion)

Compare to 0.68 – 1.62 MT CO2e / cow electricity

Fossil & Bioenergy Transportation Fuels

Source: Well-to-Wheels analysis of future automotive fuels and powertrains in the European context
WELL-TO-TANK Report Version 3.0
November 2008
Future Applications of AD Technology?
CSANR

http://csanr.wsu.edu
http://www.facebook.com/CSANR

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