Farm Sustainability

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Outline

- What is sustainable agriculture? (definition, strategies)
- Sustainability trends and issues
- Organic and sustainability
- Measuring sustainability
- Looking ahead

Sustainability

"…meeting the needs of today without compromising the ability of future generations to meet their needs."
-- UN Brundtland Commission

Sustain: to endure, to last indefinitely

Sustainability – not a threshold that is crossed, but a goal that we move towards

"A *more* sustainable farm" vs. "A sustainable farm"

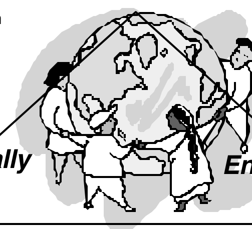
Sustainable Agriculture

Socially Acceptable

A long-term goal

Not a set of farming practices

A "3-legged stool"



Economically Viable

Environmentally Sound

Agricultural sustainability:

- Ability of farms and agricultural landscapes to evolve indefinitely under farmer management and public policy toward greater productivity of goods and services and toward effective interfaces with changing biological, economic and social environments.

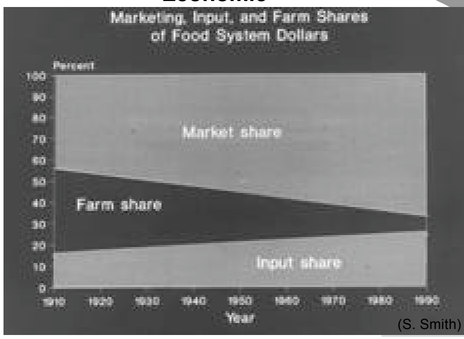
–Richard Harwood

Sustainable Agriculture

- Is easier to say what is NOT sustainable than what is
- Is best judged in hindsight
- More outcome-based than practice-based
- Sustainable is a relative term, depending on assumptions, conditions (e.g., irrigation)
- Sustainable and organic

Sustainability Issues

- Economic -



(S. Smith)

Sustainability Issues

- Environmental -

- Soil degradation
- Pesticides
- Water quality, quantity
- Atmosphere (e.g. methyl bromide)
- Energy
- Biodiversity, habitat
- Loss of farmland, urbanization


Degraded water quality

Soil Degradation


Soil erosion on the Palouse hills

Sustainability Issues

- Social -

Family farms	Farm workers
Rural communities	Human health
Food security	Fair trade
Next generation of farmers	

Global Sustainable Ag Trends

Production

- Reduced tillage
- IPM / Biocontrol of pests
- Organic farming
- Water quality protection (pesticides, nutrients, pathogens)
- Biodiversity enhancement on farms

Marketing

- More product identity – ecolabels, wine grape sustainability code, fair trade, country of origin
- Social accountability in business - SASA; sustainable business practices

Three Major Strategies for Sustainability

- Efficiency (water, spray, nutrients)
- Substitution (IGRs, microbials for organophosphates)
- Redesign (perennial polyculture)

(McRae et al., 1990)

Redesigning Farming

Albert Smith farm, southeast Minnesota

Western Iowa Watershed Design

- **Before change (ha 000)**
  - Maize 499
  - Soybean 461
  - Oat/alfalfa 13
  - Grass hay 39
  - Pasture 83
  - Perm. cover 157
  - Cow/calf pair 91,000
  - Stockers 204,000
  - Finished hogs 970,000
- **After redesign (ha 000)**
  - Maize 379
  - Soybean 269
  - Oat/alfalfa 33
  - Grass hay 100
  - Pasture 262
  - Perm cover 221
  - Cow/calf pair 251,000
  - Stockers 197,000
  - Finished hogs 7,566,400

Moved to more integration of crops and livestock

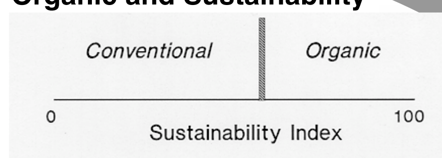
Burkhart et al. 2005. Impacts of integrated crop livestock systems on nitrogen dynamics and soil erosion in western Iowa watersheds. J. Geophysical Research (110)

Results of Redesign

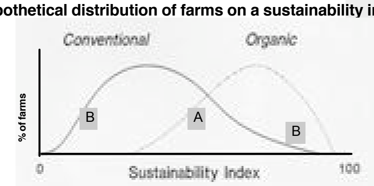
- **Wells creek watershed**
  - Sediment -56%
  - Nitrogen -63%
  - Water runoff -24%
  - Downstream
    - Cleanup cost -56%
- **Chippewa Study Area**
  - Sediment -35%
  - Nitrogen -51%
  - Water runoff -21%
  - Downstream
    - Cleanup cost -35%

Burkhart et al., 2005

Organic and Sustainability



Hypothetical distribution of farms on a sustainability index



The European Experience

Indicators	++	+	0	-	- -
Ecosystem		x			
Soil (erosion, OM)		x			
Ground and Surface Water (leaching)		x			
Climate and Air			x		
Farm Input and Output (nutrient, water, energy use)		x			
Animal Welfare and Health			x		
Quality of Produced Food		x			

Legend: ORG compared to CONV: **++** much better, **+** better, 0 same, - worse, -- much worse

Stolze et al, 2000: The Environmental Impacts of Farming in Europe

Nitrate Leaching Rates - Europe

Reduction in nitrate leaching from organic farms compared to conventional	Authors
>50%	Smilde (1989)
>50%	Vereijken (1990)
57%	Paffrath (1993)
40% (sand) 0% (loam)	Blume et al. (1993)
50%	Reitmayr (1995)
40%	Berg et al. (1997)
64%	Haas (1997)

(Scialabba and Hattam, 2002)

TOXINS

Few toxins used in organic ag; natural products presumed safer than synthetic

Pesticide impacts – Environmental Impact Quotient (EIQ)

Red Delicious apples, NY	Theoretical EIQ
Conventional	938
IPM	167
Organic	1799

(Kovach et al., 1992)

Golden Delicious apples, WA (6 yr)	
Conventional	3464
Conv w/ PMD	2893
Integrated	2211
Organic	466

(Reganold et al., 2001)

BIODIVERSITY

Organic farms generally have:

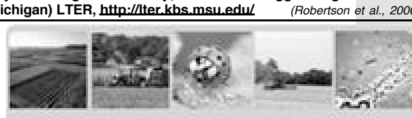
- **More plant diversity (30-350% increase in floral species diversity in organic fields in Europe)**
- **More genetic variation (local varieties, no GMOs)**
- **Greater faunal diversity (insects, soil fauna and microbes, birds)**
  - **Denmark – 2-3x more birds on organic farms, more species**
- **Often more habitat, landscape diversity on organic farms; buffer zones, pastures**

(Scialabba and Hattam, 2002)

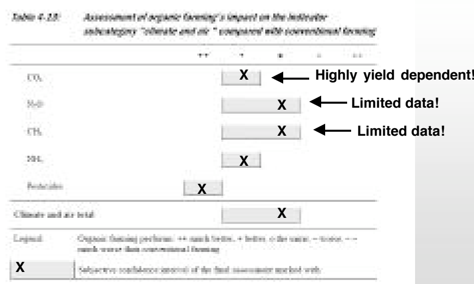
Greenhouse Gases

	CO_2					g CO_2e/ m^2/yr
System	Soil C	N fert	Lime	Fuel	N_2O	Net GWP
Conv. till*	0	27	23	16	52	114
No till*	-110	27	34	12	56	14
Organic	-29	0	0	19	56	41
Alfalfa	-161	0	80	8	59	-20
Early forest	-220	0	0	0	15	-211

10 year Michigan field study; *C-S-W Kellogg Biological Station (Michigan) LTER, http://lter.kbs.msu.edu/ *(Robertson et al., 2000)*

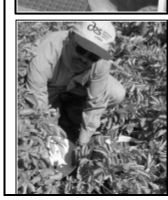


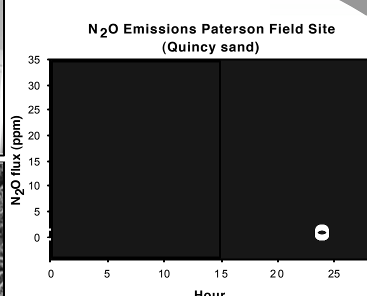
European assessment on Organic



Organic Farming in Europe: Economics and Policy Volume 6, chapter 4.2.3 "Climate and Air"

N_2O Flux: Paterson WA





Courtesy: H.Collins,USDA-ARS

Sustainability Questions and Assumptions for Montana Organic Grain Production

Energy

Climate

Water

Soil Quality

Weeds

Markets

Sustainability Questions and Assumptions

Energy

Petroleum:
- Farm equipment
- Hauling crop to market
- Delivery of inputs

Options:
- Energy conservation
- Reduced tillage
- Biofuels – biodiesel, 1 ac fuels 10 ac
- Electric
- Sunshine Farm

Sunshine Farm Experiment

50 acre crop and livestock farm, Kansas – 10 year study

Energy generated on farm per year	236 GJ
Annual energy needed	263 GJ
"Amortized" embodied energy	154 GJ

Will be a challenge to provide excess energy from agriculture

(M. Bender, 2003)


Home-made biodiesel

Shifting the Paradigm: Current Solar Income

- More solar energy intersects the earth in 24 hours than is contained in all of the conventional oil reserves the world has (not all of this solar energy could be captured).
- 40 min of sunlight = annual global energy use

Source: G. R. Davis. Energy for planet earth. Scientific American. September, 1990, p. 55-62.

ENERGY – the fundamental 'currency' of life

Solar Energy Capture

	Usable Energy
Total solar energy hitting earth	100%
↳ Non-absorbed wavelengths (60%)	40%
↳ Reflection and transmission (8%)	32%
↳ Heat dissipation (8%)	24%
↳ Plant metabolism (19%)	5%
	⬇ Carbohydrate

100 Kcal solar energy yields max. 4-5 Kcal chemical energy stored per gram dry matter of biomass

(Taiz & Zeiger, 2002)

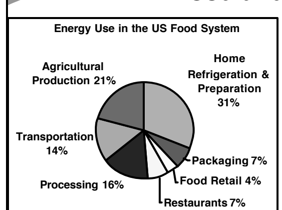
Energy Ratios

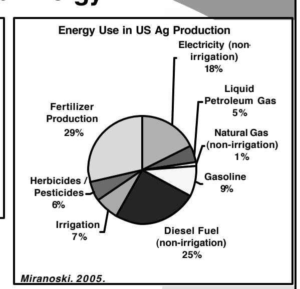
Usable energy recovered per unit energy invested

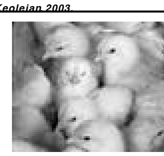
Oil	20-100:1 (declining)
Gas, coal	10-30:1
Solar, wind	3-10:1
Renewables from ag, tar sands	5:1 or less
Ethanol (corn)	1.26-1.33
Ethanol (cellulosic)	4-10 ?
Biodiesel (soy)	3.2
Fischer Tropsch	10 ?

Caution: method of calculation is not uniform

Food and Energy







Food = Sunshine + Oil

Farms use about 3% of energy consumed in US

Energy Use

Organic as % of Conventional

Product	GJ/ha	GJ/ton of product
Winter wheat	35-59	57-79
Potatoes	54-73	71-107
Milk	31-77	46-85
Apple	90	123

(Scialabba and Hattam, 2002)

Sustainability Questions and Assumptions

Climate

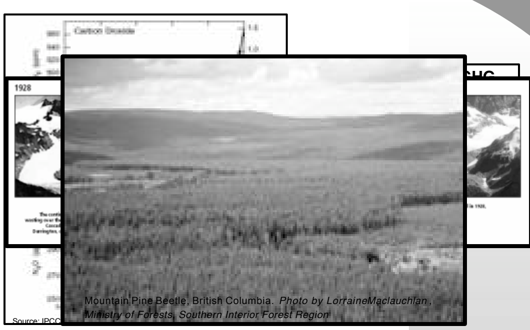
Warming trend likely – could improve crop productivity. Ave. temperature Helena, ? 1.3°F over past 100 yr

Effect on moisture less clear; precipitation has decreased by up to 20% in many parts of the state

Model predictions by 2100:

- Temperatures ? 4°F (range 1-8°F) in spring and summer; ? 5°F (range 2-10°F) in fall and winter
- ? frequency of extreme hot days in summer
- Precipitation ? 10% spring, summer, fall; ? 15-40% winter
- Summer streamflows likely reduced

Greenhouse Gases and Climate Change



Mountain Pine Beetle, British Columbia. *Photo by LorraineMaclauchlan, Ministry of Forests, Southern Interior Forest Region*

Source: IPCC

Sustainability Questions and Assumptions

Water

Directly related to climate

Surface capture – snow barriers; Keyline

Infiltration and storage – soil structure, SOM

ET losses – soil, weeds

Water Use Efficiency for crops - fallow

Sustainability Questions and Assumptions

Soil Quality

NOP – "…maintain or improve soil and water quality…"

Carbon balance

Ratio of C and N

Tillage

Nutrient balance, budgets – N, P

Organic vs No-till Wheat - Montana

Bozeman study, 2000-2003

Organic: winter pea-winter wheat-spring lentil-spring barley; no fall tillage, direct seed pea into barley stubble

Lower spring soil nitrate; slower biomass accumulation, less summer drought stress, higher NUE ?

Pea and lentil provide equivalent of 105 lb N/ac

ORG test wt consistently higher than NT

P response (cereal, legume, N fixation); ORG may need P inputs over time

Miller et al., 2008

Phosphorus Over the Long Term

NE Montana soil

Olsen P = 4-10 ppm; harsh extractable P = 250 ppm; If 250 ppm in 6", = 500 lb P/ac

Grain exports ~0.2 lb P/bu/yr. So 30 bu crop removes 6 lb P/ac/yr, soil contains "80 yr" supply of P if it can be made plant available

Strategies:

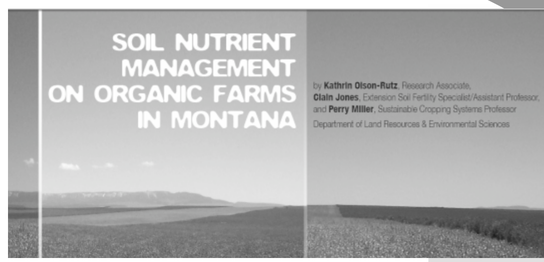
? Diverse rotations – different rooting depths, different ability to solubilize and take up P (e.g. buckwheat has acidic rootzone that liberates P, but may not carry over to next crop)

? Mycorrhizal associations – different strains, improved crop genetics to encourage symbiosis

? P solubilizing organisms – *Penicillium*

? Amendments

Source: C. Jones



Expected late 2010

Sustainability Questions and Assumptions

Weeds

Tillage – conflicts with soil quality

New weeds

Warming climate, weeds are more competitive

Sustainability Questions and Assumptions

Markets and Economics

Expanding consumer base – so far

Competition – local grain production, artisan bakers

Prices

Role of nutritional quality

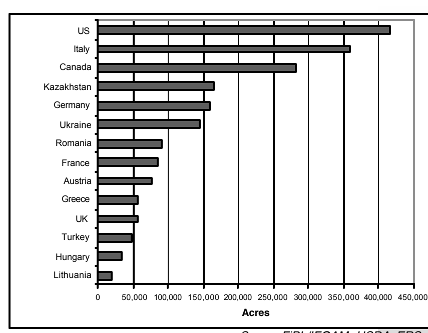
Organic Wheat Trends

Global organic cereals (2008)
4.92 million ac

Global organic wheat
2.12 million ac total
1.56 million ac cert

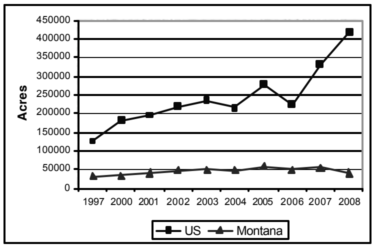
2008 - 1.33 mil ha of organic cereals in EU, up 250,000 ac from 2007

Leading Organic Wheat Producers 2008



Source:FiBL/IFOAM, USDA-ERS, AgCanada

US Organic Wheat 2008



US	415,902
CO	57,631
UT	53,760
MT	39,389
CA	36,115
ND	34,170
TX	33,506
SASK	223,000

Source: USDA- ERS

Wheat Production – Saskatchewan

	Yield (bu/ac)	Income	Costs	Returns
		- - - - - -	C$/ac	- - - - - - -
Conv.	33	95	50	46
Top Mgt.	32	81	52	31
Org.	31	84	40	44
Org. w/ prem.	31	125	48	77

(Rutherford et al., 1992)

Wheat Yield Reduction Northern Plains

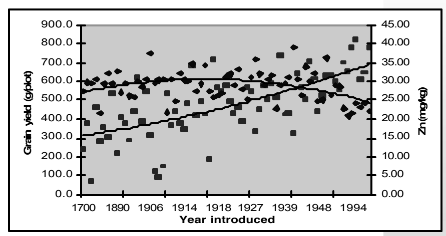
Scenario	% Yield Reduction
No herbicides	30
No insecticides or fungicides	3
No synthetic N	13
No herbicides or fungicides	32
No herbicides or N	39
No I, F, or N	15
No agrichemicals	41

(Smith et al., undated)

Mineral Content (2004-2005)

Historical (1700-1962) vs Modern (1985-2000) Spring Wheat

- Cu, Zn, P, Mg content: Historical > Modern ($p < 0.05$)
- Fe, Se, Mn, Ca content: no significant difference



Jones, Murphy, & Reeves

Environmental Sustainability

Organic farming can:

- Reduce soil erosion and nitrate leaching, improve soil quality
- Reduce the use of fossil fuels
- Enhance wildlife and biodiversity
- Reduce the release of toxins into the environment

How do we measure sustainability in agriculture?

System comparison studies
- long term studies
- do they use the latest technology?

Established standards
- soil erosion (tolerable soil loss)
- water quality (10 mg/L nitrate)
- pesticide residues, worker exposure

Indices – soil quality, Env. Impact Quotient

Economics – profitability, new farmers

Social – family farms, community impacts, food quality and human health

No single unifying measure

Farming Systems Study
South Dakota 1985-1992

	Org.	Conv.	RT
Direct costs (not labor) ($/ac)	45	62	69
Net income 1986-92 (not mgt.) ($/ac)	37	23	6
Surface residue in spring (%)	43	22	42
NO_3- N (lb/ac) 30-60 cm depth	26	88	36
Whole farm energy inputs (DFE)	2657	8275	9024
Productivity			
lb TDN/$ invested	22	16	14
lb TDN/hr labor	1312	1237	1245
Herbicides applied (lb a.i. whole farm)	0	459	595

Based on a 500 acre farm. *(Smolik et al., 1993)*

What is a footprint ?

A measure of the impact of a system, practice, or product on one or more environmental factors; need a reference point

Food miles – ignores production energy, different transport forms

Energy use – renewable or not; primary or embedded; input/output ratios

Other non-renewables – water, mined minerals,

Footprint cont'd

Emissions – GHG, odor, acid rain, toxins (pesticides)

- EIQ (NY) Apple: Conv. 938, IPM 167, Organic 1799
- EIR (WA) Apple: Conv+MD 2893, IFP 2211, Organic 466
- Protected Harvest - Toxicity Units per acre

Carbon footprint – specifically CO_2 and/or other gases in CO_2e

Life Cycle Assessment (LCA) – air, water, energy, biodiversity, … social

Footprint cont'd

Ecological footprint – the amount of resource area needed to support a given lifestyle
?2003 ave. global biol. capacity 1.8 ha/person
?US footprint 9.6, Switzerland 5.1, China 1.6

Many qualitative programs – set a threshold of practices
?Food Alliance – pest management, soil & water, safe and fair working conditions, biodiversity

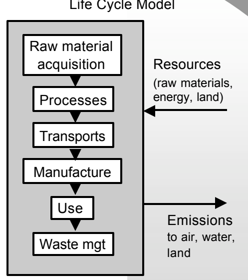
Footprint mostly measures negatives; need to include positives.

Life Cycle Assessment

Started in the 1970s as an *environmental* analysis tool; "cradle to grave"; initial focus on industrial, manufacturing processes; ISO 14400 standard.

Steps:
- Goal and scope definition
- Inventory analysis
- Life cycle impact assessment
- Interpretation and presentation of results

Life Cycle Model



Baumann and Tillman, 2004

Life Cycle Assessment

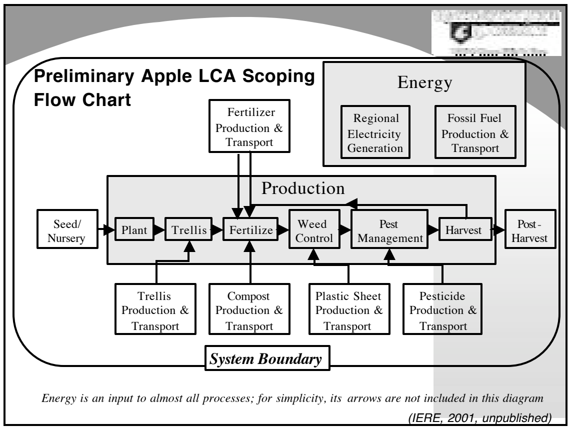
Key method issues: functional unit; system boundaries and allocation; type of data used; impact assessment

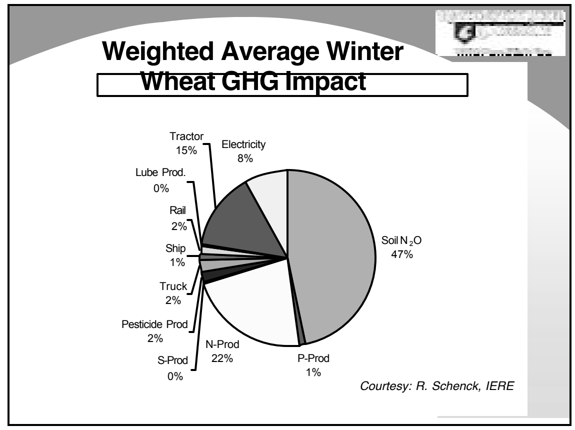
Impacts measured:
?Depletions: fossil fuel, water, mineral
?Land use / biodiversity
?Air - GHG, acidification, smog, airborne toxicity, ozone depletion
?Water - aquatic toxicity, eutrophication

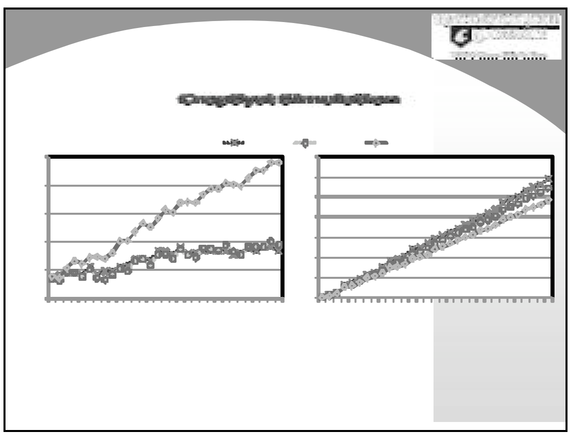
Extensive literature, many groups, some international harmonization

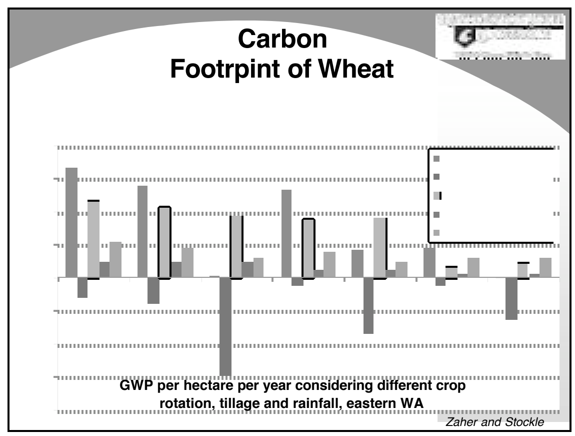
American Center for Life Cycle Assessment
http://www.lcacenter.org/

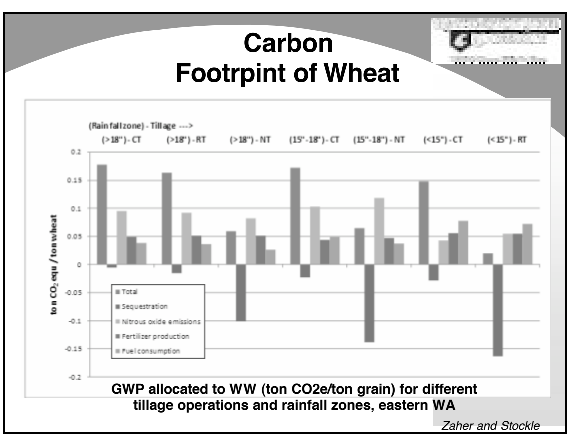
Institute for Environmental Research and Education
http://www.iere.org/sustain/LifeCycle.htm

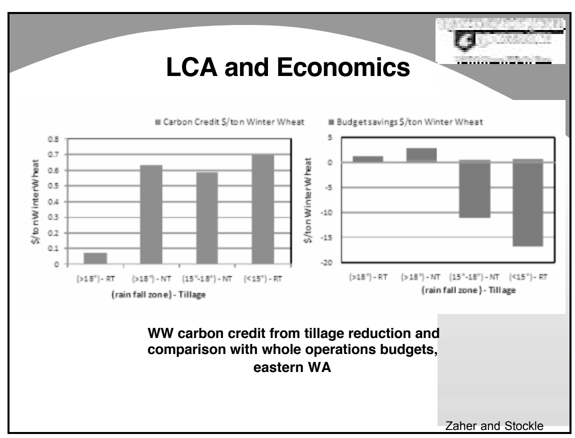

Preliminary Apple LCA Scoping Flow Chart
Energy
Regional Electricity Generation
Fossil Fuel Production & Transport
Fertilizer Production & Transport
Production
Seed/ Nursery
Plant
Trellis
Fertilize
Weed Control
Pest Management
Harvest
Post-Harvest
Trellis Production & Transport
Compost Production & Transport
Plastic Sheet Production & Transport
Pesticide Production & Transport
System Boundary
Energy is an input to almost all processes; for simplicity, its arrows are not included in this diagram
(IERE, 2001, unpublished)


Weighted Average Winter Wheat GHG Impact
Tractor 15%
Electricity 8%
Lube Prod. 0%
Rail 2%
Ship 1%
Truck 2%
Pesticide Prod 2%
S-Prod 0%
N-Prod 22%
P-Prod 1%
Soil N2O 47%
Courtesy: R. Schenck, IERE




Carbon Footrpint of Wheat
GWP per hectare per year considering different crop rotation, tillage and rainfall, eastern WA
Zaher and Stockle

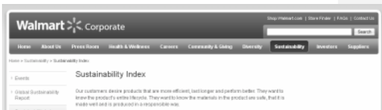

Carbon Footrpint of Wheat
(Rainfall zone) - Tillage --->
(>18") - CT
(>18") - RT
(>18") - NT
(15"-18") - CT
(15"-18") - NT
(<15") - CT
(<15") - RT
Total
Sequestration
Nitrous oxide emissions
Fertilizer production
Fuel consumption
GWP allocated to WW (ton CO2e/ton grain) for different tillage operations and rainfall zones, eastern WA
Zaher and Stockle


LCA and Economics
Carbon Credit $/ton Winter Wheat
Budget savings $/ton Winter Wheat
(rain fall zone) - Tillage
WW carbon credit from tillage reduction and comparison with whole operations budgets, eastern WA
Zaher and Stockle

Looking Ahead

Markets – growth is not unlimited; competing issues, e.g., local; make organic wheat more unique

Other sustainability initiatives – baseline assessments now



Energy – begin exploring alternatives now before a petroleum crisis

Sustainable P sources – nutrients from cities to farms?

Enhancing Future Sustainability

Perennial wheat, other perennial crops

Organic wheat breeding – yield, nutrient use eff., weed competitiveness, grain nutrient content, mycorrhizal association

Cover crop breeding – water use eff., climatic adaptability, small seed size, rhizobial association

Intercropping – grain / legume

Microbial amendments – P solubilizers, associative and free living N fixers, improved rhizobiua, PGPR, weed suppressive species (e.g. *Pseudomonas*)

Enhancing Future Sustainability

Reduced tillage, direct seeding

Less fallow

Increase soil organic matter

Livestock integration

Innovation and co-operation – limitless, renewable resource!

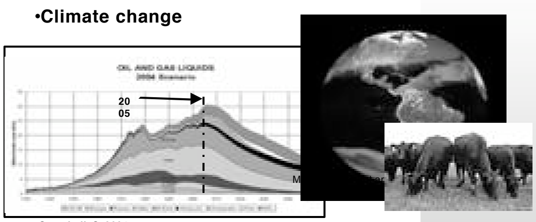
Thank You !

Future Sustainability

Mega-trends:

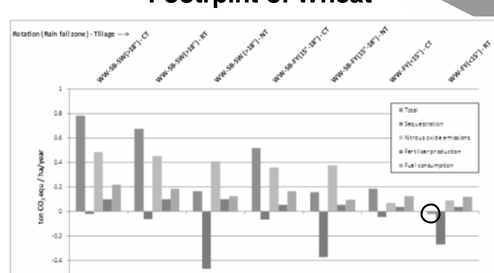
•Peak oil

•Climate change



Campbell, C. 2004

Carbon Footrpint of Wheat



GWP per hectare per year considering different crop rotation, tillage and rainfall, eastern WA

Zaher and Stockle

Global Warming Potential

	Sequestered Carbon	N_2O Losses	Net GHG Emission
	Kg CO_2e/ ha-year		
Lind CT	100	187	87
Lind RT	200	327	127
Othello CT	750	1634	884
Othello RT	650	1120	470
Othello NT	750	1984	1234

Modeled using CropSyst

Courtesy: R. Schenck, IERE

Which Parts of the Footprint to Consider

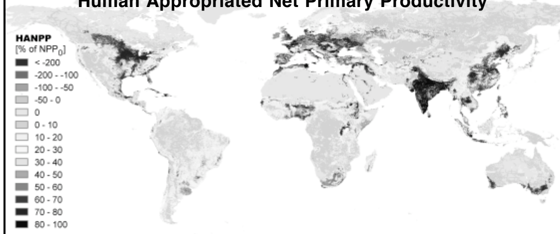
- - - - - GWP (Mg CO_2e/ac/yr) - - - - -

	C seq.	N_20	Fert.	Fuel	Net
Wheat-fallow	-0.11	0.04	0.015	0.05	-0.005
Wheat-barley-wheat	-0.19	0.17	0.030	0.04	0.050

Reduced till for wheat-fallow

No-till for wheat-barely-wheat

Human Appropriated Net Primary Productivity



Sustainability implies 'limits'

- Terrestrial only
- Global estimates HANPP = 3 to 39%

Environmental Sustainability

Organic farming <u>can</u>:

- Reduce soil erosion and nitrate leaching, improve soil quality
- Reduce the use of fossil fuels
- Enhance wildlife and biodiversity
- Reduce the release of toxins into the environment