Sustainable intensification
What is it, and why is it vital?

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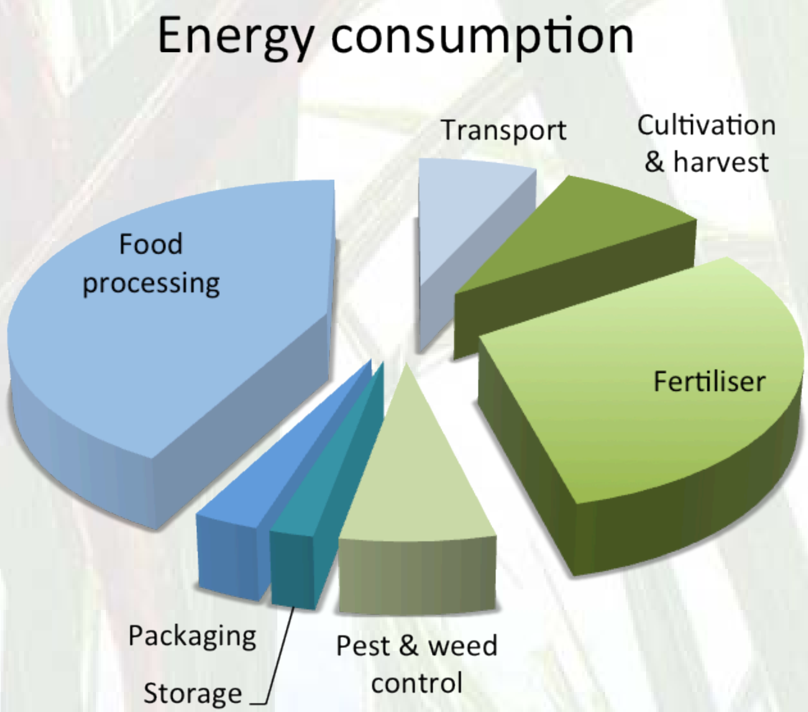
Sustainable intensification

Sustainable	intensification
Low input	High input
Organic	High technology
Small farms	Huge, industrial farms
Eco-friendly	Reduced biodiversity
Low yield	High yield
High cost products	Cheaper products

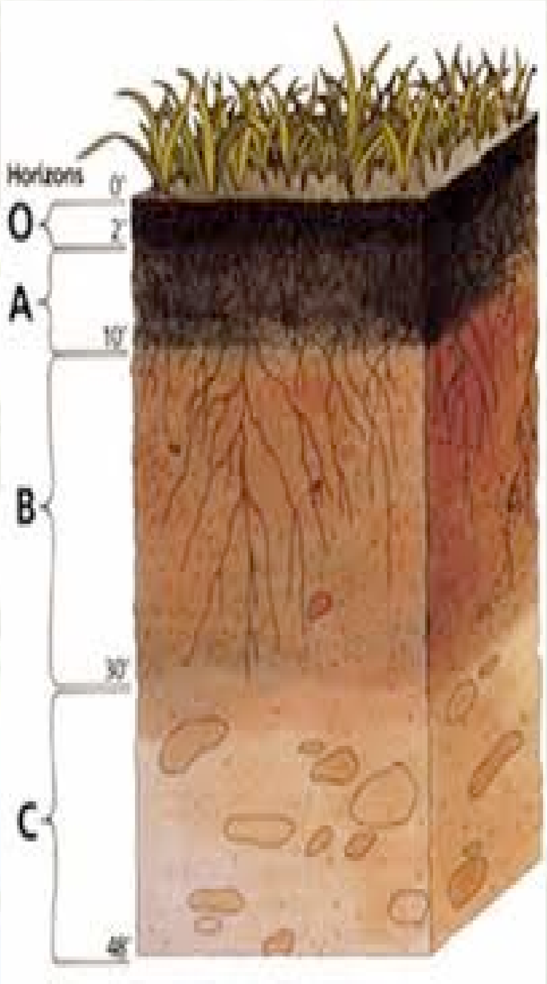
Food is a net energy consumer, GHG emitter

- Solar energy offset by:
  - fertilizer energy
  - post-harvest
  - machinery & transport fuel
- Nitrogen fertilizer uses:
  - 1% global energy
  - 4% global natural gas
- Agriculture causes 10-12% GHG emissions
  - CH_4 from animals, rice
  - N_2O from fertlizer



Soil health declining

- 24% of available land degraded by human activity
- Erosion rate ~100x replacement
  - ~500yr to create 2.5cm
- Limited understanding
  - soil biology & plant interaction
  - optimisation of nutrient uptake
- Reductions in:
  - particle sizes
  - soil carbon levels



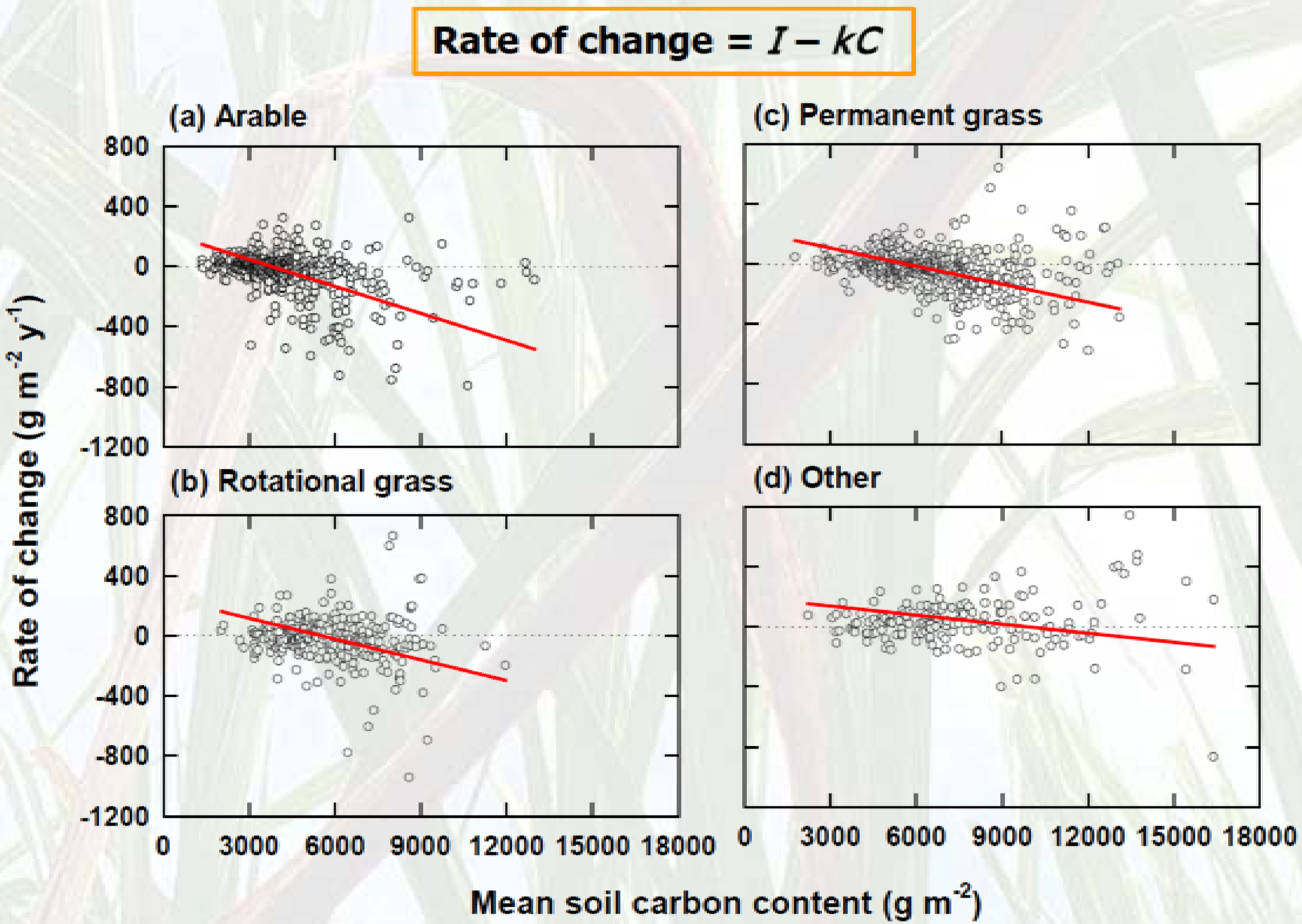
Intensive soils losing structure

- Yield related to soil particle size
  - optimum >250μm
- Trend to smaller soil particles in intensive agriculture
- *Likely* loss of yield

Particle size distribution. % of mass		
	Crop	Set-aside
>2000μm	16.6	29.6
1000-2000μm	2.9	8.1
250-1000μm	26.5	27.9
53-250μm	23.7	15.9
<53μm	10.1	5.6
>250μm	45.8	65.5

Stamati *et al.* (2011) J. Env. Qual.

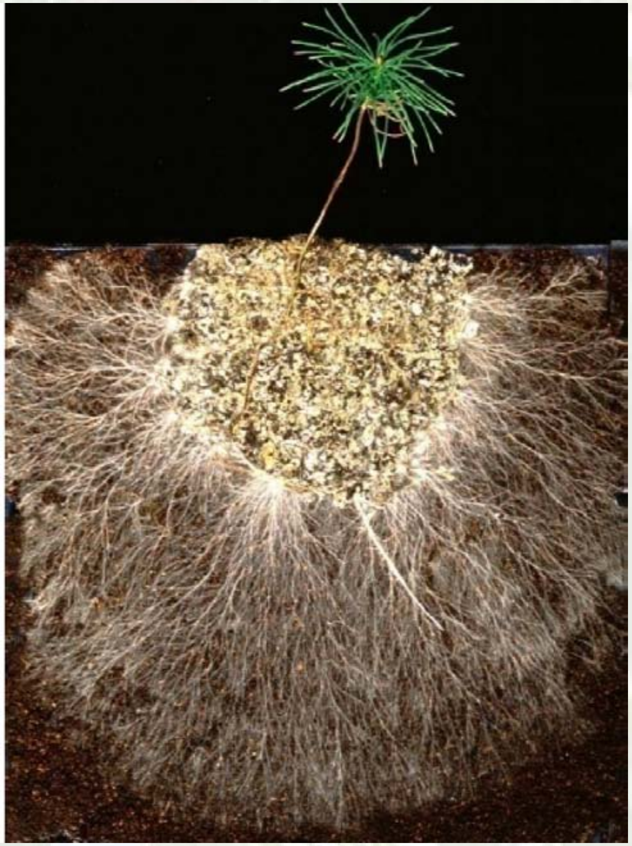
Decline of UK soil carbon since 1978



Kirk & Bellamy (2010) Eur. J. Soil. Sci. **61**, 401-411

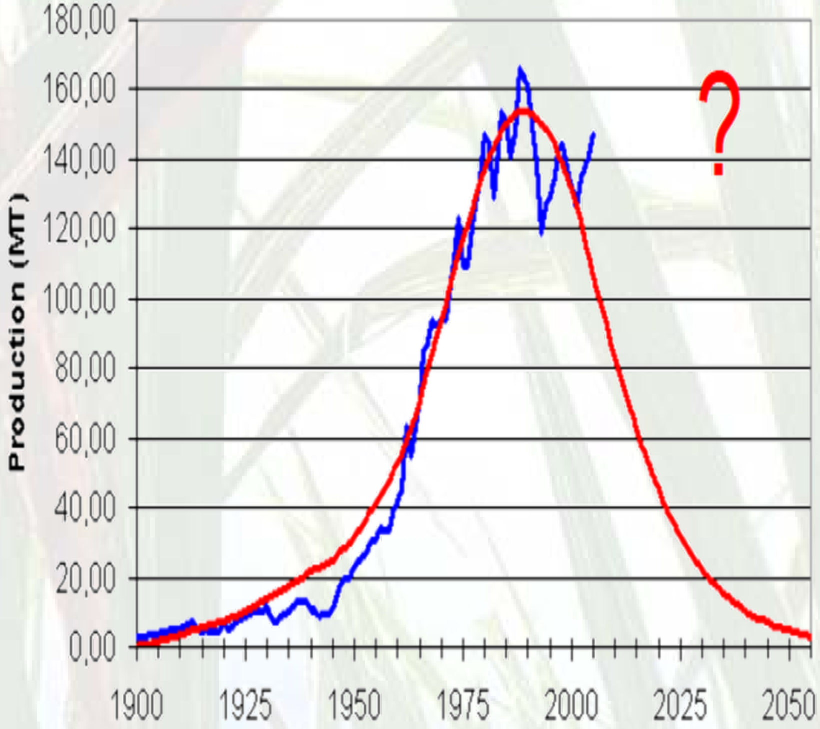
90% of plants are mycorrhizal

- Major role in plant productivity
- ~30% N & P uptake
- With roots, 50% soil carbon
- 200km mycelia per kg
- Biology little explored
  - 25% of global species
  - <1% identified

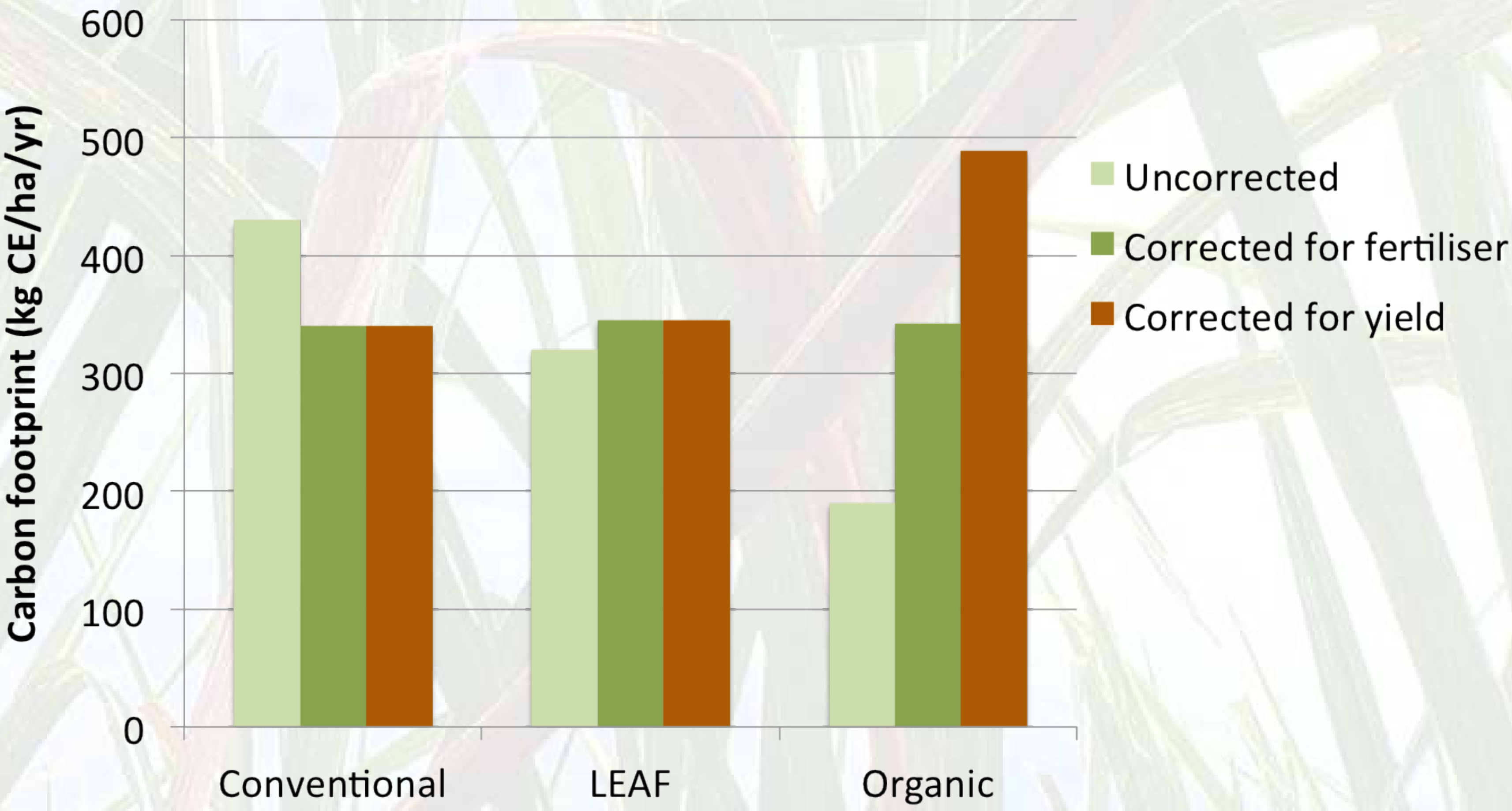


Running out of available Pi

- Pi abundant globally
- Running out of concentrated sources
  - 200yrs forecast exhaustion
- Current usage:
  - inefficient
  - loses Pi to groundwater & oceans



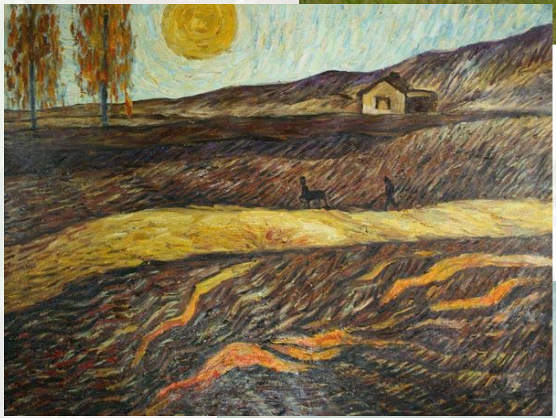
Organic does not lower carbon footprint



Sources: Hillier *et al.* (2009) J. Ag. Sust., **7**, 107-118
USDA-NASS (2008) Survey of Organic Agriculture in US

Agriculture has major ecological impact

- Deforestation continuing in some places
- Massive ecological shift from forest ➠ arable or grassland
  - much of what is considered “natural” landscape is due to past agriculture

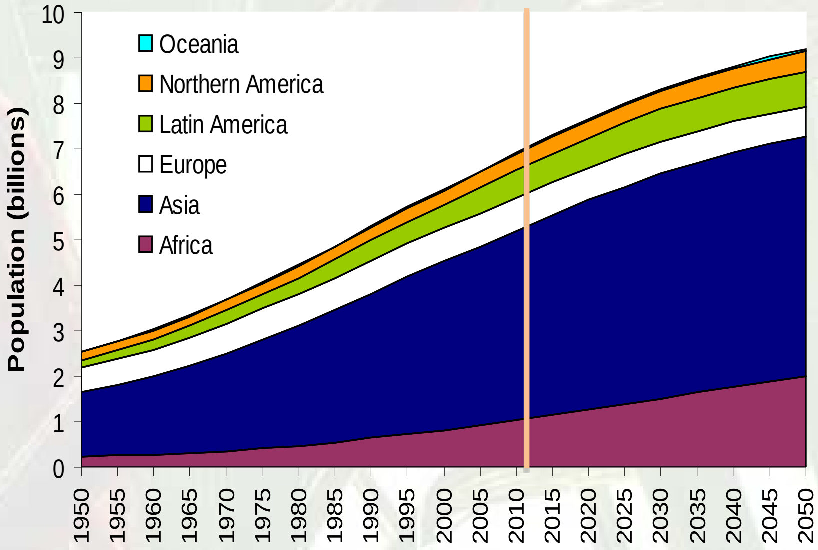


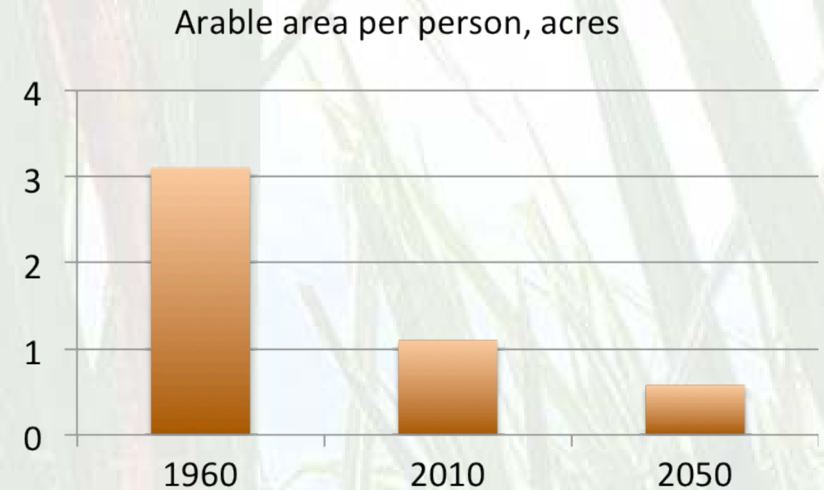
Conclusion

- No current paradigm for agriculture meet the challenge of sustainable intensification:
  - high yield
  - sustainable:
    - energy use
    - nutrient use
    - water use
    - soil health
    - biodiversity

Productivity is absolutely vital

- At least 2bn more people to feed by 2050
- Shrinking area of food production per head
  - no new land
  - urban growth ongoing
  - need to preserve forests
- Risk of climate change increasing lossses

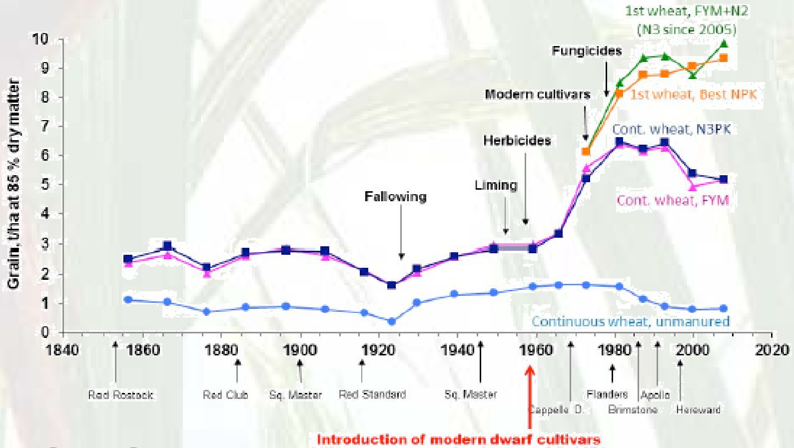




Sources: United Nations, World Population Prospects
UNEP

Have to face some difficult realities, *e.g.*

- Agriculture will still need ~70% fresh water
  - plants need water for hydrogen, transport, cooling
  - limited scope for changing the fundamentals
- Plants need fixed nitrogen for good yield
  - synthetic fixation uses energy
  - biological fixation reduces yield
  - recycling through manure releases GHG



Source: Rothamsted, Broadbalk data

Sustainable intensification requires major changes

- Macro level
  - consumption
  - grain v. grass, “waste” for animal feed
- Agricultural level
  - better energy balance
  - more efficient use of water, nutrients
  - soil health
- Societal/environmental level
  - definition of local & global biodiversity needs
  - protocols to meet this need

Reasons to believe

- Drought tolerance
- Irrigation
  - reduced waste, deliver other treatments
  - lower energy water purification
- Lower energy N fixation
  - Haber process
  - increased use of “green fertilizer”
- Increased understanding of soils
  - optimisation of Pi and N
  - optimisation of soil C

Some horticultural crops approach sustainability

- Unheated; heated by digestion of waste
- Soil-free
- On-demand:
  - water
  - nutrients
- Biological control
- CO_2 enrichment

Measuring success is vital, but tricky

- Resource efficiency
  - C footprint a good start
  - soil health
  - yield per unit water, energy, nutrient

Field to market: Keystone Alliance

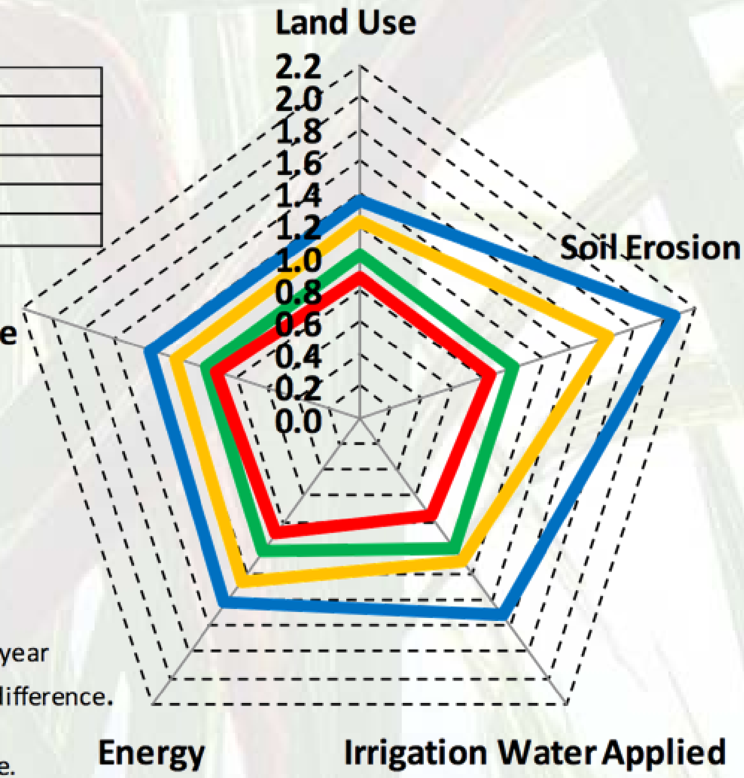
- Collaborative stakeholder group
- Defining, measuring sustainability of food, fibre production
- Outcome-based metrics
- Environmental & socioeconomic impacts
- Tools to help growers

Per bushel impact of US crops improving

Index of Per Bushel Resource Impacts to Produce Corn for Grain (United States, Year 2000 = 1)

Year	2000 *	Unit - per Bushel
Land Use	0.008	Planted Acres
Soil Erosion	0.038	Tons
Irrigation Water Applied	0.242	Acre Inches
Energy	49,372	Btu
Greenhouse Gases	13.4	Pounds CO_2e

* Five-year average 1996 - 2000



Note: Data are presented in index form, where the year 2000 = 1 and a 0.1 point change is equal to a 10% difference. Index values allow for comparison of change across multiple dimensions with differing units of measure.

Figure 1.1 Index of Per Bushel Resource Impacts to Produce Corn for Grain, United States, 1980-2011

Field to Market (2012). Environmental and Socioeconomic Indicators for Measuring Outcomes of On-Farm Agricultural Production in the United States: Second Report, July 2012. Available at: www.fieldtomarket.org.

Measuring success is vital, but tricky

- Resource efficiency
  - C footprint a good start
  - soil health
  - yield per unit water, energy, nutrient
- Ecological impact

Difficulty measuring biodiversity

- Is productivity possible in balanced ecosystem?
- More feasible option:
  - preserve maximum amount of diverse, balanced ecosystems
  - maximise productivity with contained impact
- Social values may oppose straight science, *e.g.*
  - people value the look of hill farms
  - ecologists could argue should revert to forest

Measuring success is vital, but tricky

- Resource efficiency
  - C footprint a good start
  - soil health
  - yield per unit water, energy, nutrient
- Ecological impact
- Ideal may be a simple traffic-light system
  - consumers understand & drive competition in the food chain
  - updated to reflect progress and new science

Sustainable intensification

- Productivity to feed everyone a healthy diet
  - requires behavioural change
- Preservation of wild ecosystems
- Reduced use, recycling of resources
  - nutrients
  - water
- Preservation of soil health
  - including carbon sink
- Balanced economics
  - profitable for growers, affordable for consumers, stable supply