The Sustainable Intensification of Agriculture: Options and Challenges

The 35th T B Macaulay Lecture,
James Hutton Institute, Aberdeen
27th September 2012

Professor Jules Pretty OBE
University of Essex

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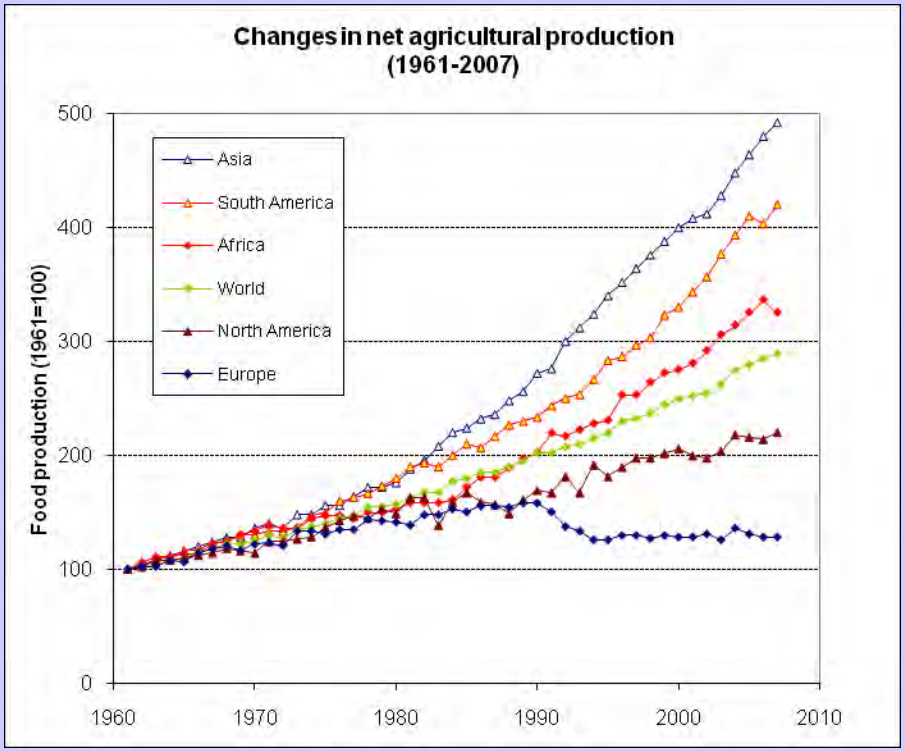
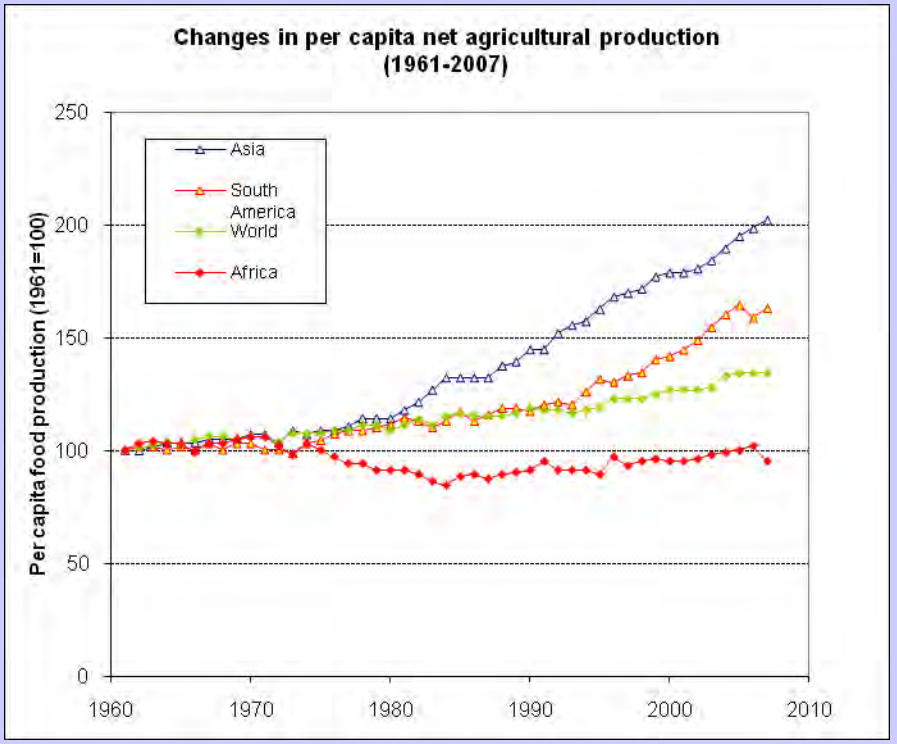
Mixed progress on food: the past 50 years





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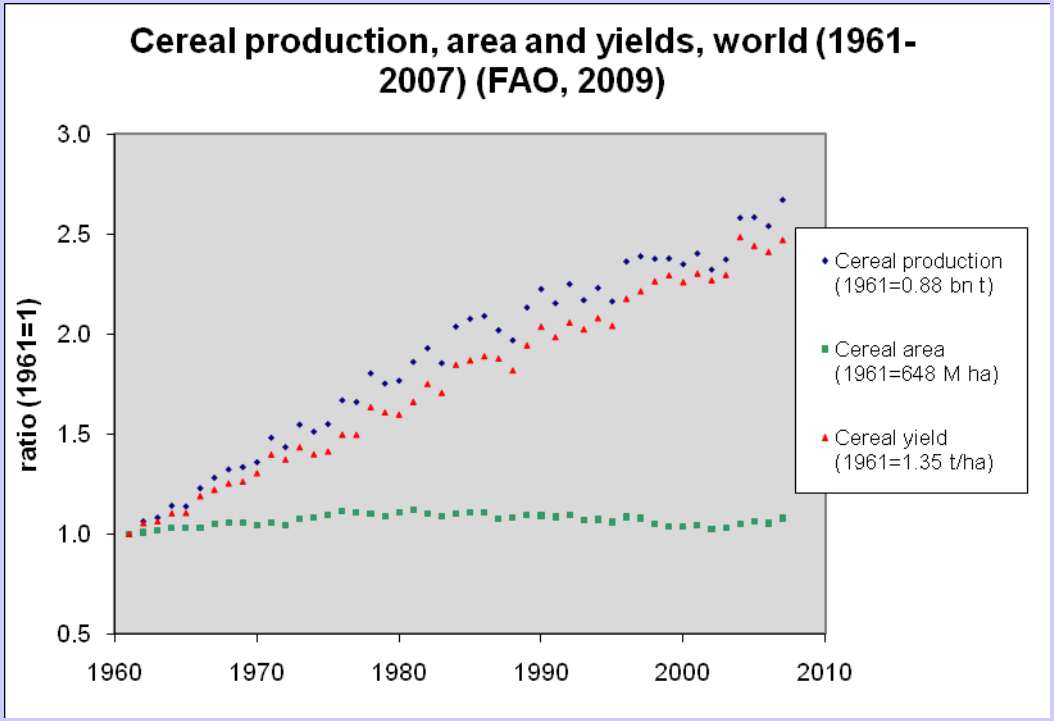

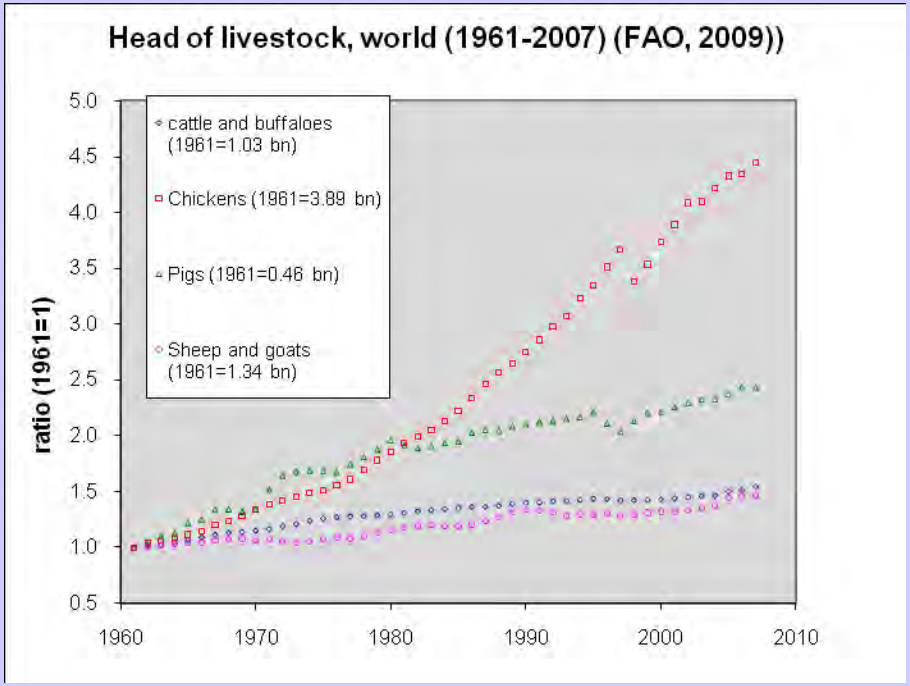

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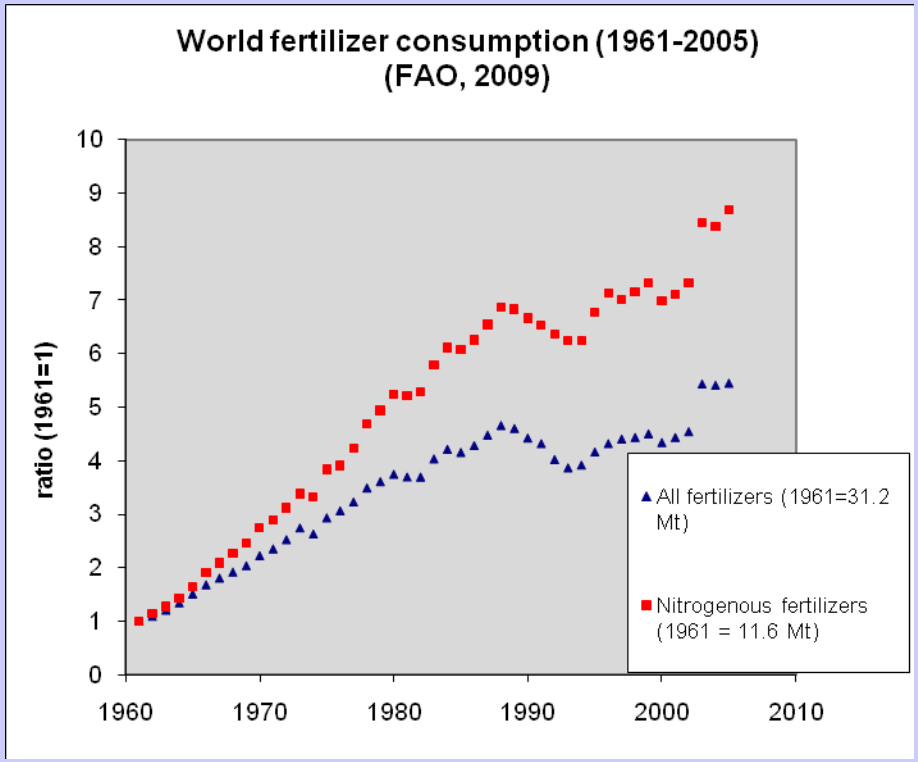
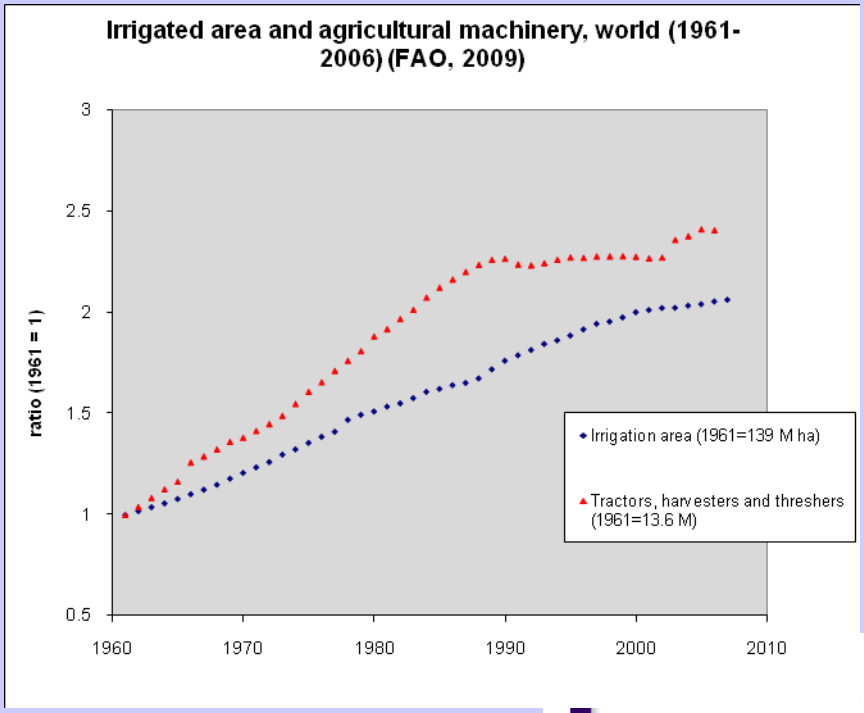
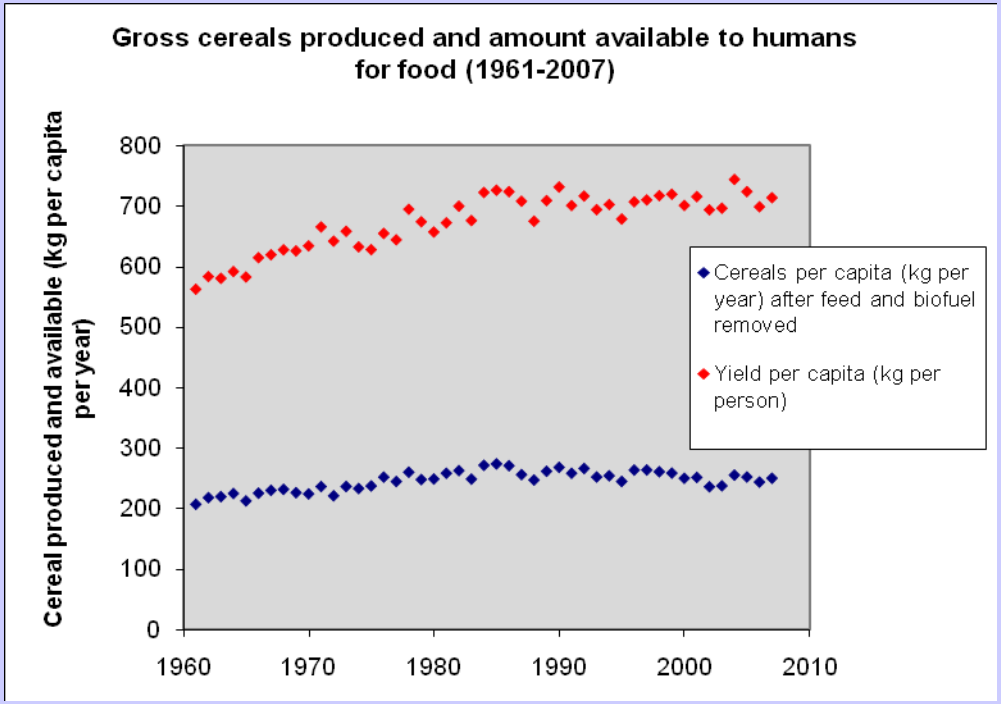
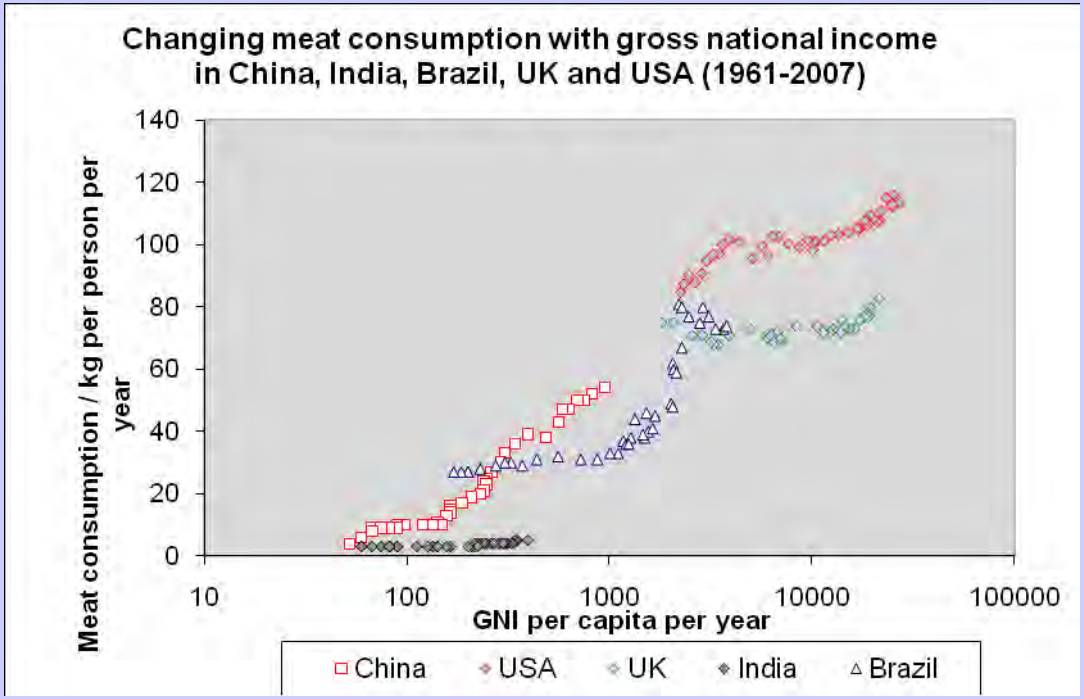

World fertilizer consumption (1961-2005)
(FAO, 2009)
ratio (1961=1)
10
9
8
7
6
5
4
3
2
1
0
1960
1970
1980
1990
2000
2010
All fertilizers (1961=31.2 Mt)
Nitrogenous fertilizers (1961 = 11.6 Mt)


Irrigated area and agricultural machinery, world (1961-2006) (FAO, 2009)
ratio (1961 = 1)
3
2.5
2
1.5
1
0.5
1960
1970
1980
1990
2000
2010
Irrigation area (1961=139 M ha)
Tractors, harvesters and threshers (1961=13.6 M)





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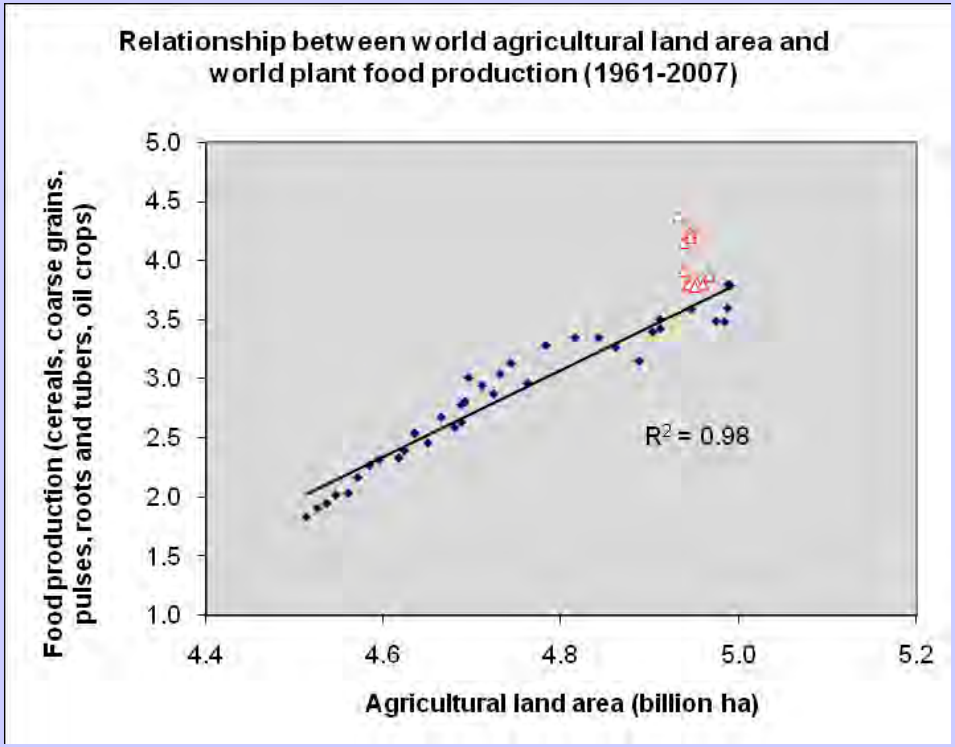
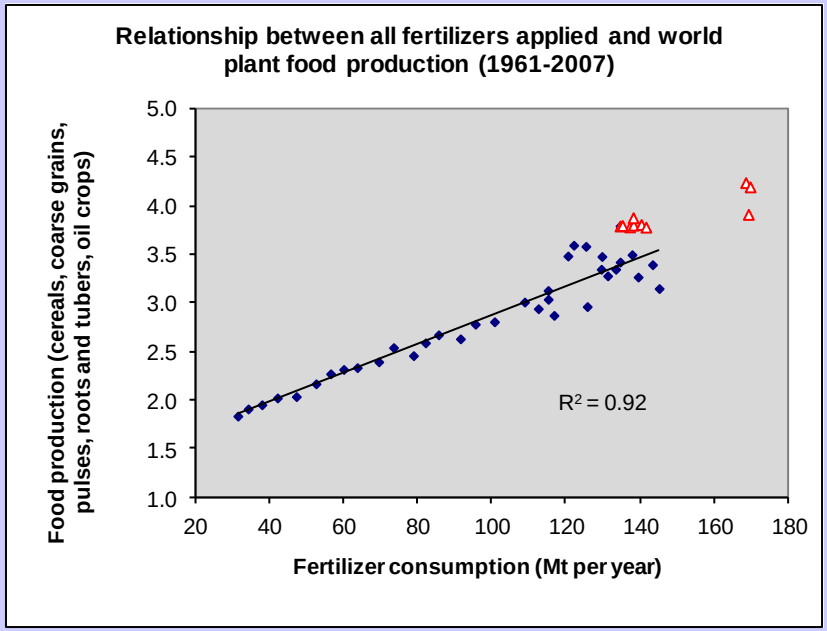
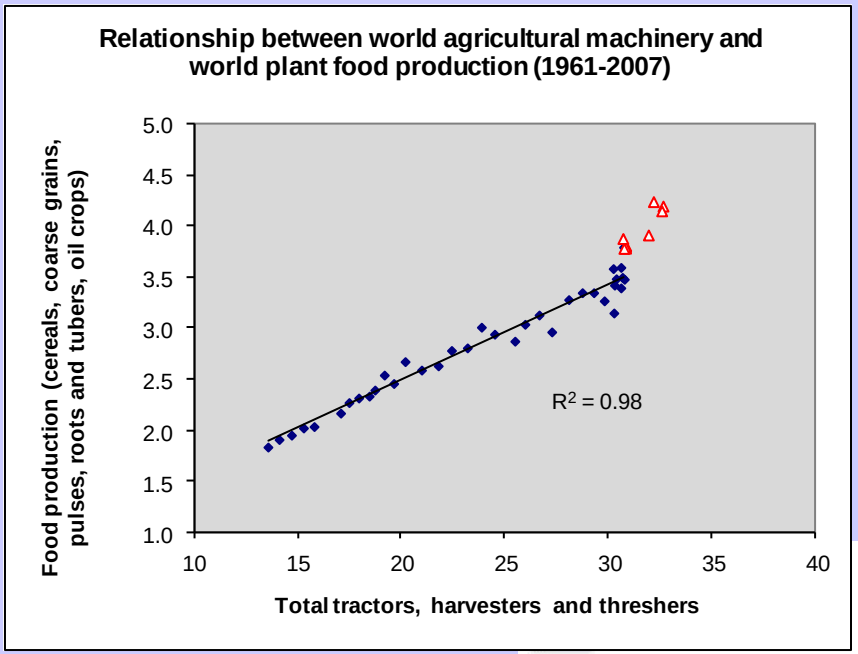

Relationship between world agricultural land area and world plant food production (1961-2007)
Food production (cereals, coarse grains, pulses, roots and tubers, oil crops)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
4.4
4.6
4.8
5.0
5.2
R2 = 0.98
Agricultural land area (billion ha)


Relationship between all fertilizers applied and world plant food production (1961-2007)
Food production (cereals, coarse grains, pulses, roots and tubers, oil crops)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
20
40
60
80
100
120
140
160
180
R2 = 0.92
Fertilizer consumption (Mt per year)


Relationship between world agricultural machinery and world plant food production (1961-2007)
Food production (cereals, coarse grains, pulses, roots and tubers, oil crops)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
10
15
20
25
30
35
40
R2 = 0.98
Total tractors, harvesters and threshers

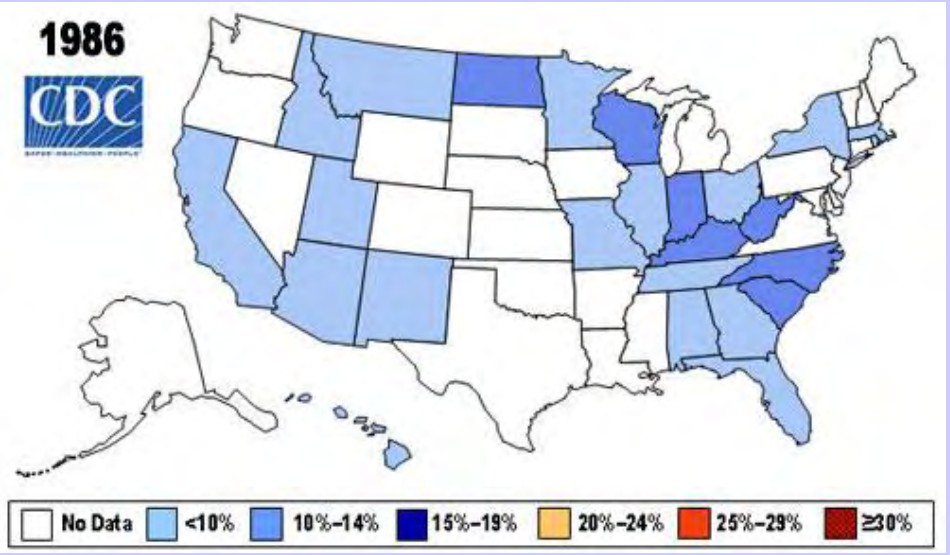
New Threats

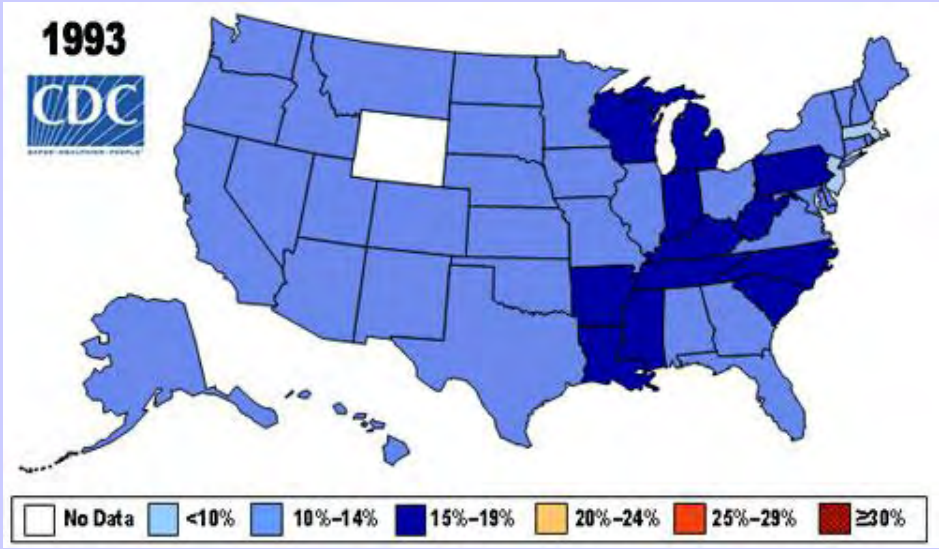
- Consensus: world food system in new danger

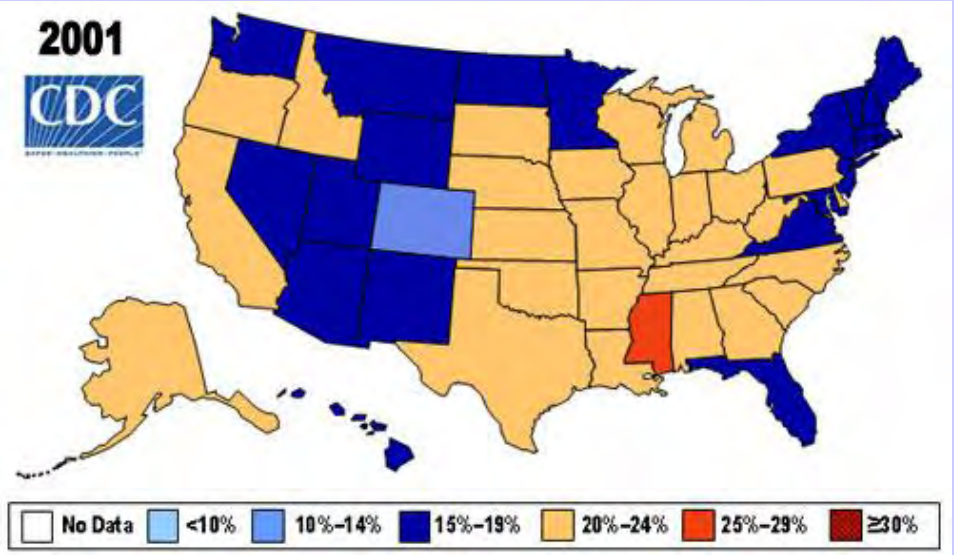
  - Consumers expect to be able to buy food anywhere, anytime
    - But also now disconnected from food production
    - Nature of shortages forgotten by many
    - Emergence of obesity pandemic
  - Biofuels
    - Cereals into ethanol
  - Climate change
    - IPCC predicts 50% yields cut in much of Africa (by 2020-30) and other threats
    - Agriculture also important contributor to GHGs
  - Converging consumption patterns
    - Food price uncertainty (doubled 2005-2008; fell back, spiked again late 2010, then 2012)

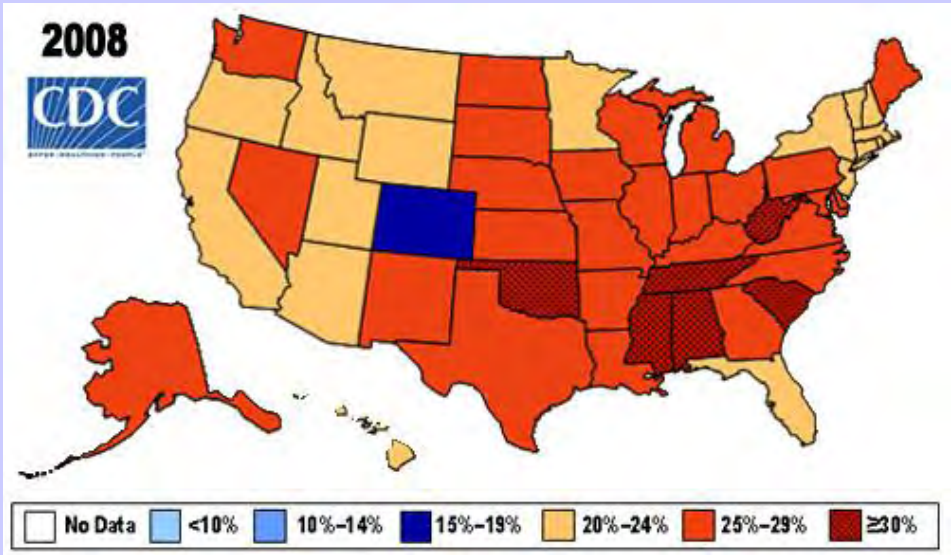
Pretty *et al* (54 authors) 2010. The top 100 questions of importance to the future of global agriculture. *Int J Agric Sust* 8(4), 219–236

Change in Adult Obesity, US (BMI ≥ 30), 1986-2008









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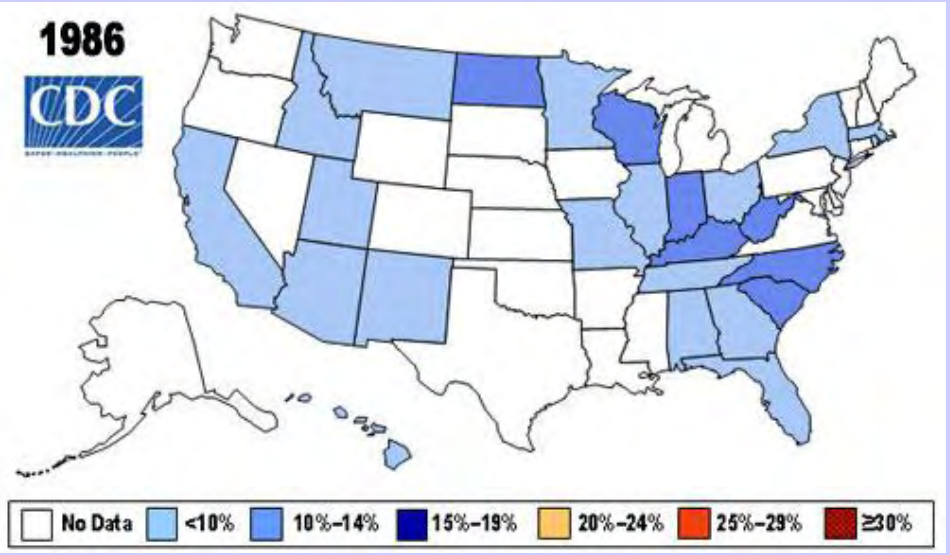
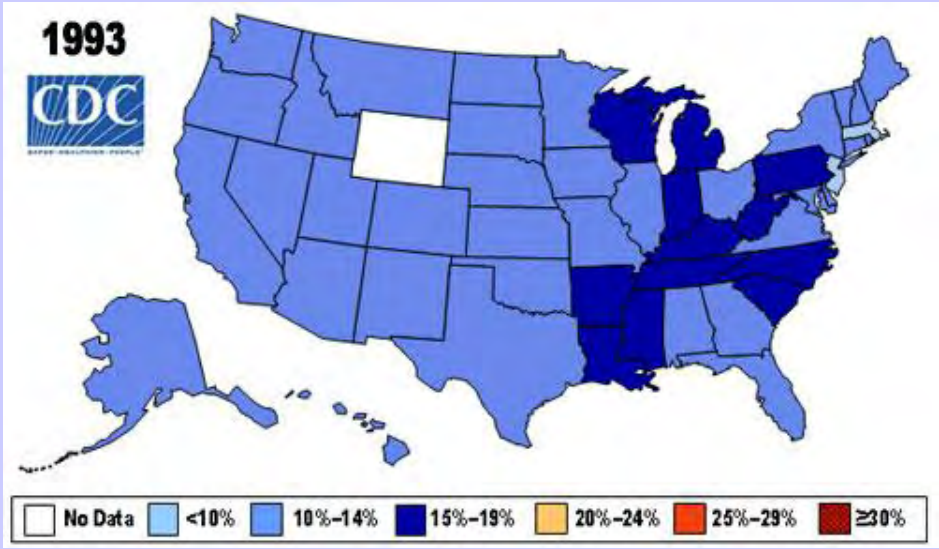
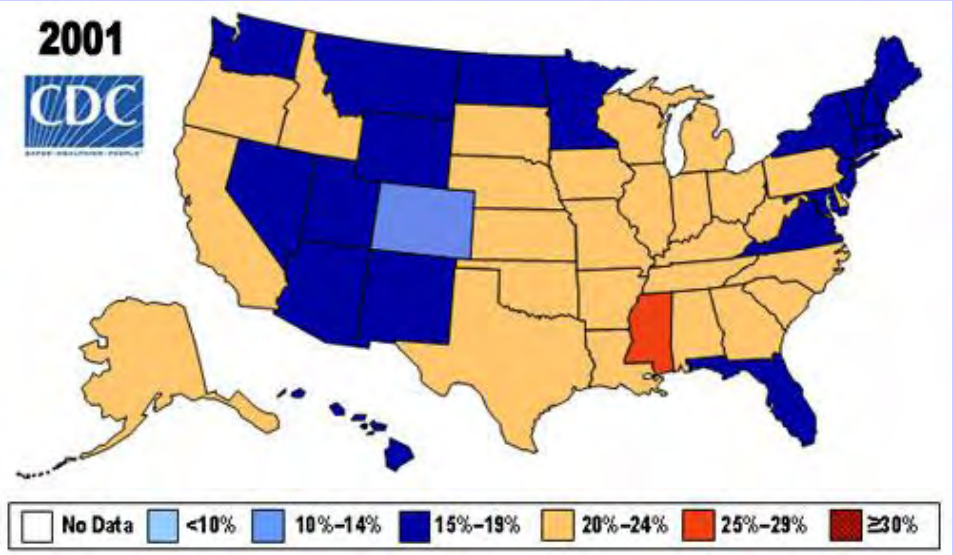
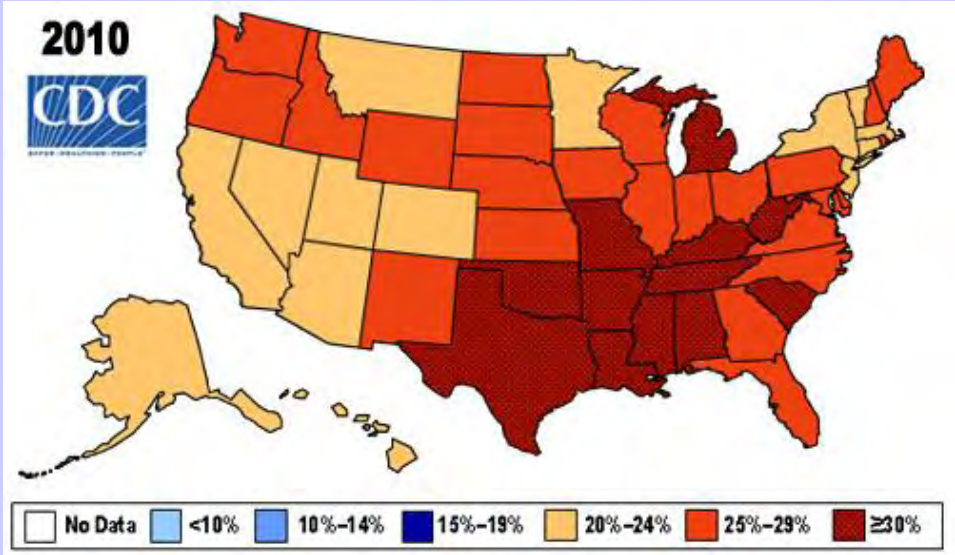






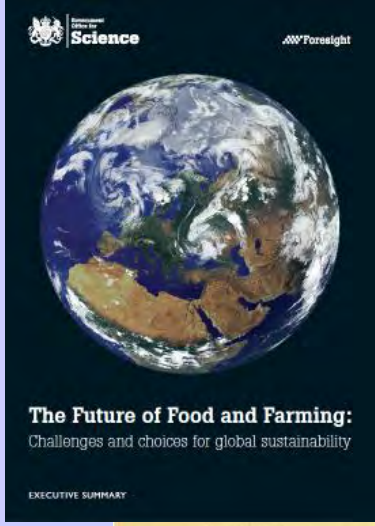


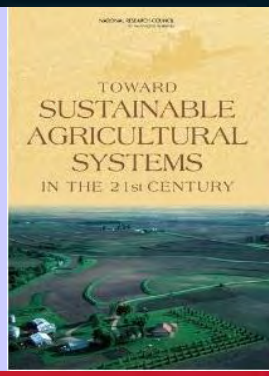
Sustainable intensification: Emerging consensus

- Major problems ahead
  - Need a substantial (50-100+%) increase in food production worldwide by 2050
    - But not at cost to important environmental services
    - Will need the best of science and social innovation

- Sustainable intensification: aims
    - Increase yields
    - Increase positive environmental side-effects
    - Decreased negative side-effects
    - …On the same land

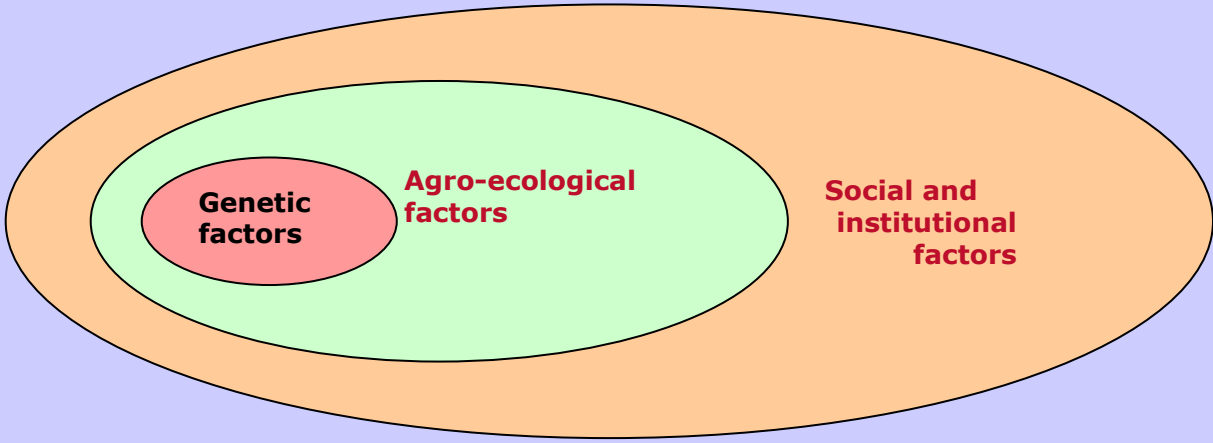
  - *Both* improvements in crops *and* improvements in agro-ecological management
    - Make the best of all technologies, approaches and farming methods





GCARD 2010
GLOBAL CONFERENCE ON AGRICULTURAL RESEARCH FOR DEVELOPMENT

Sustainable intensification



- Both agricultural + environmental outcomes are sought
  - Cannot be defined by any particular technologies or practices
  - When work best = contribute to environmental services
- Two components to technologies and practices
  - Crop varieties and livestock breeds
  - Agro-ecological processes to manage agricultural and wider habitats
  - Both-and, not either-or
- Human and social capital for innovation and delivery
  - Human capital – knowledge and capacity to adapt and innovate
  - Social capital – work together to solve common agricultural and natural resource problems

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Agro-ecological knowledge

- Application of ecological knowledge to agricultural systems
  - Scientists, extensionists, farmers
- Use of ecosystem services provided by plants, animals and micro-organisms and by physical resources
  - Study of soils, pests and predators, water, trees, organic matter
  - Predation, parasitism, nitrogen-fixation
  - Scale and hierarchy
- Tendency is towards diverse agro-ecosystems with multi-functional components
  - Integrated technologies and practices complement best seeds and breeds

Social capital

- Relations of trust that lubricate co-operation
- Common rules, norms and sanctions for behaviour
- Connectedness and social institutions

- 3 types
  - Bonding, bridging and linking social capital

- Fundamental basis for sustainability
    - lowers the costs of working together
    - facilitates co-operation between people
    - increases flows of knowledge and understanding
    - maintains cultures

  - 500,000 new social groups established worldwide in late 1990s-2000s

Sustainable Intensification: some evidence

- Two University of Essex studies
  - 286 cases in 57 countries (2006)
  - 30 cases in Africa (2011) (commissioned by Foresight)

- Approx 20 million farmers adopted sustainable intensification in 2000s

- Yields: mean increase of 1.67x (286 cases) and 2.13x (Africa)

Pretty *et al*. 2006. *Env Sci & Tech* 40 (4), pp1114-19

Pretty, Toulmin & Williams (eds) 2011. IJAS 9(1), pp1-289

Food improvements: sustainable intensification

- **Additive**
  - New components
    - eg fish
  - Small patches
    - Raised beds for vegetables
  - Land rehabilitation
    - Formerly degraded becoming productive
  - More livestock per household
    - More fodder trees
  - New crops or trees
    - eg pigeonpea, domesticated indigenous trees
  - Short-maturing vars permitting 2 crops/yr
    - eg orange fleshed sweet potato, Uganda

- **Multiplicative**
  - Increased yields per hectare
    - New varieties and new management
    - mean across projects **2.13x increase**

Integrated Pest Management in rice

Learning to make best use of beneficial insects & arthropods

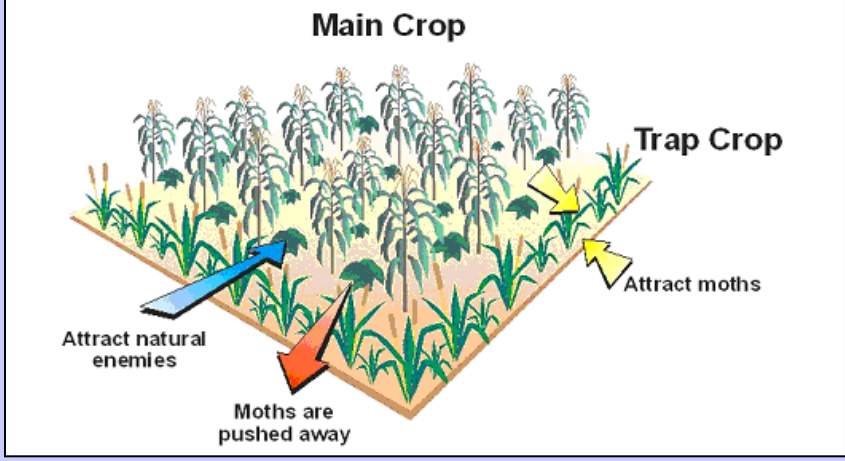
Farmer field schools

IPM in rice: farmer field schools

- Farmers attend farmer field schools (`schools without walls') during whole rice season
  - meet each week to learn new agro-ecological principles for rice and pest management

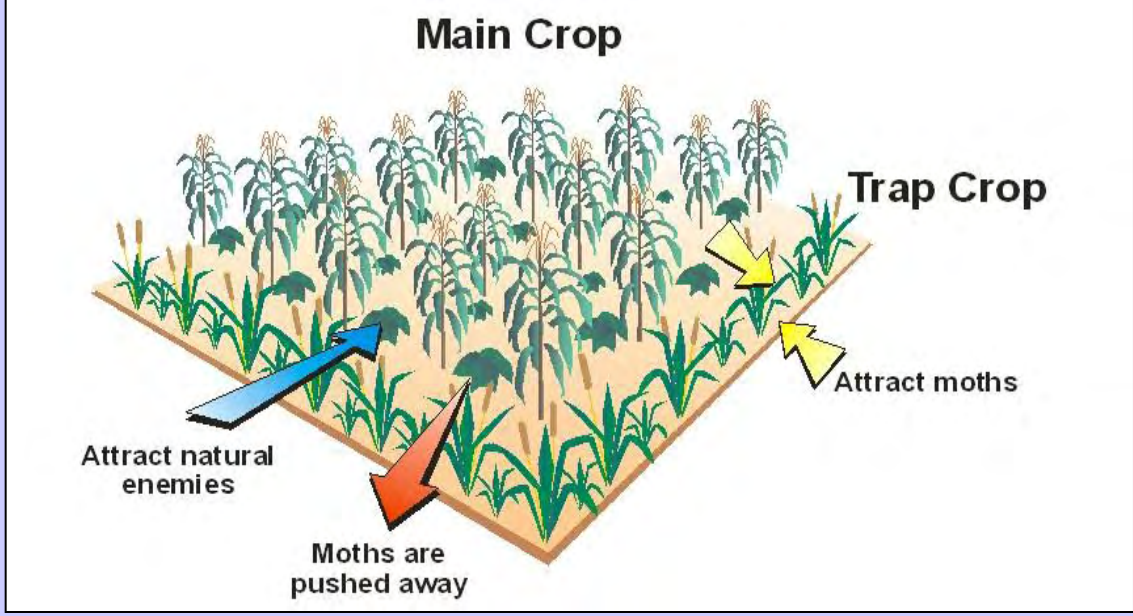
- 4 million farmers trained in 175,000 FFS
    - Indonesia 1.1 m; Vietnam 930,000; Bangladesh 650,000; Philippines 500,000; India 255,000
- Outcomes
    - Rice yields up 5-7%;
    - Costs of production down (Bangladesh ~ 80% of trained farmers use no pesticides)
    - Fish-rice-vegetable systems produce synergistic benefits
- Senegal, Burkina Faso, Mali, Benin
    - Farmer field schools for IPM and crop management
    - Rice, market garden vegetables, cotton, mango
    - 50,000 farmers trained and adopted

Pest management

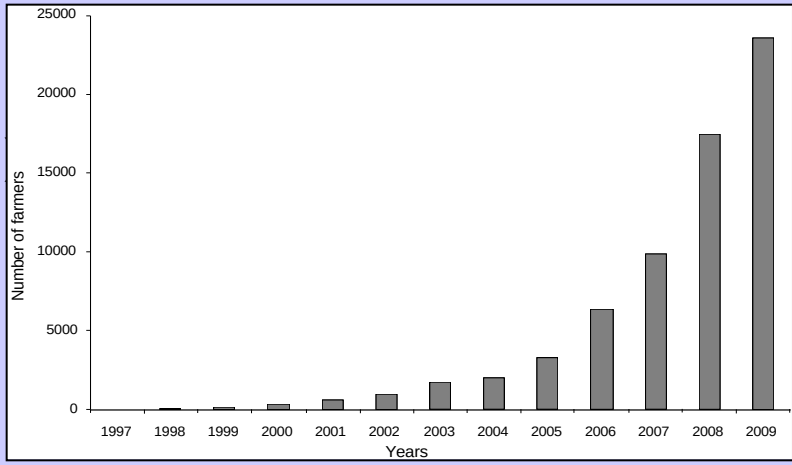


- Sound and novel science
- Introduction of new system components
  - Redesigned agricultural systems
- Building of social and human capital
- Farmer learning and training
  - 3500 FFS in West Africa
  - Mixtures of technologies

Push pull IPM, Kenya



- Locally available plants as perennial intercrop and trap crops
- Needs understanding of chemical ecology, agrobiodiversity, plant-plant and insect-plant interactions
- *Desmodium* repels stemborer moths (push) and also attracts natural enemies
- Attractant trap plant, *Napier* grass (pull) planted as a border crop around this intercrop.
- Stemborer females are repelled from the main crop and attracted to the trap crop



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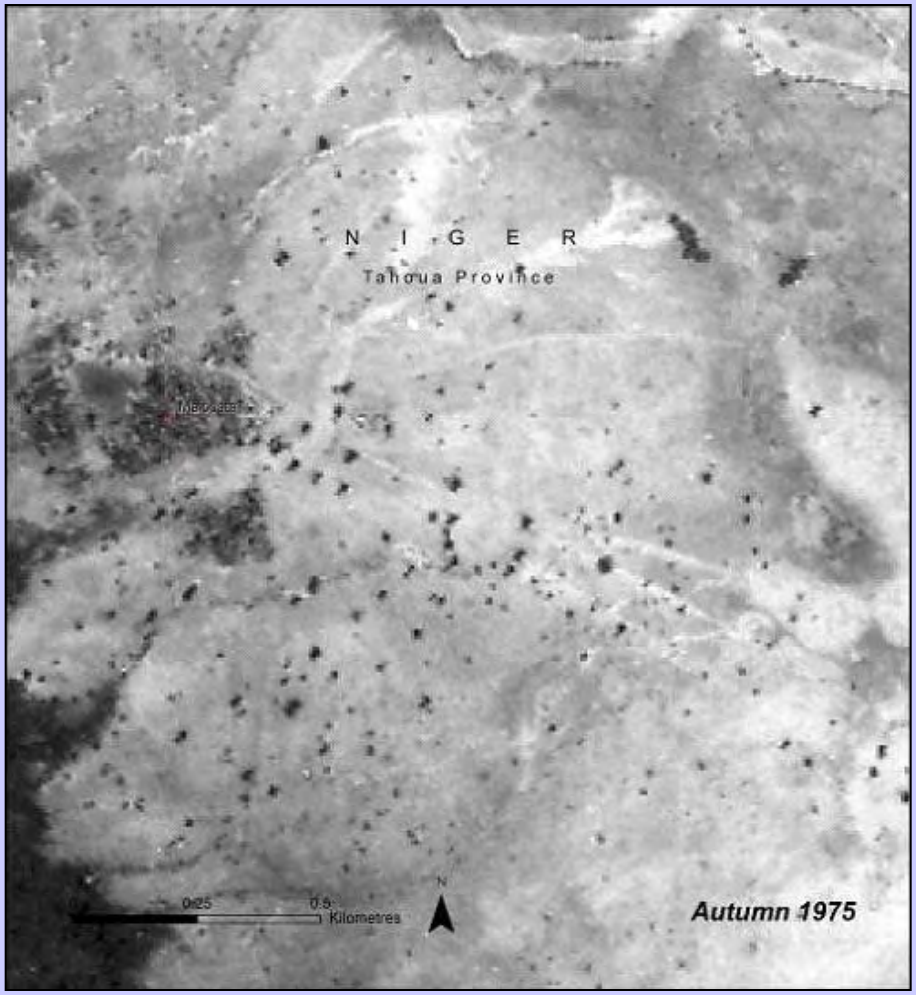
Soil Conservation & Agroforestry

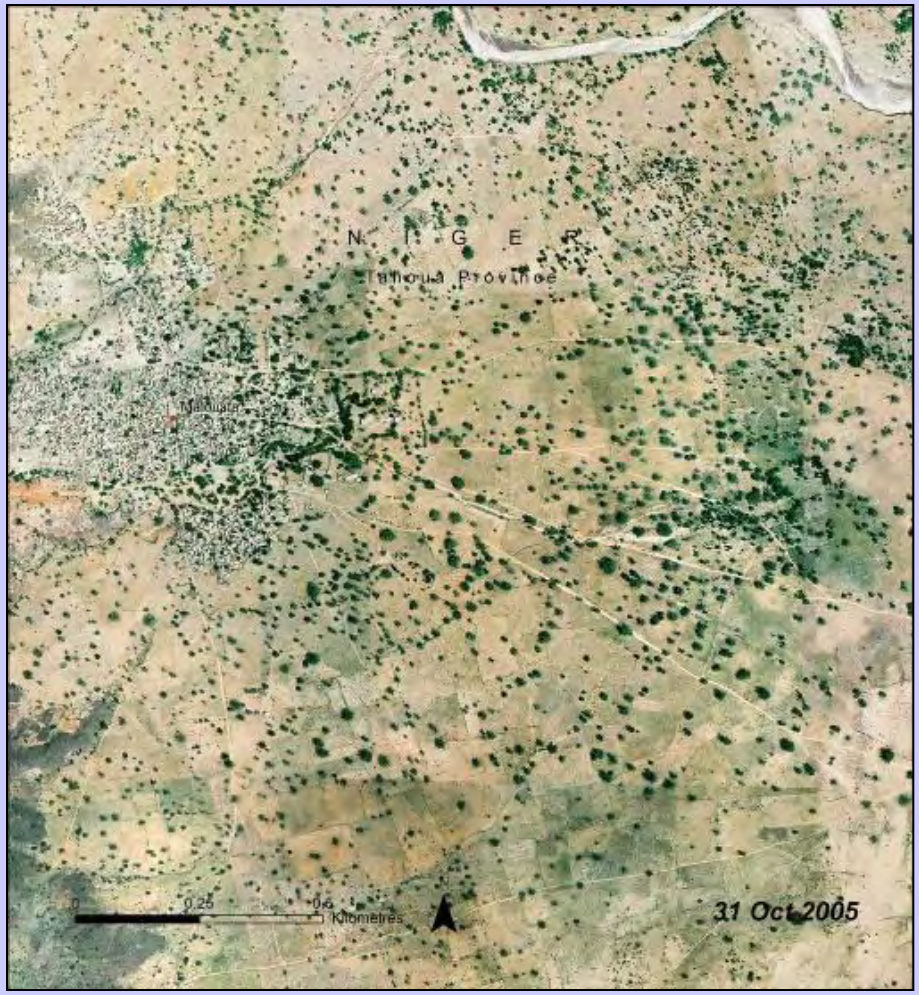
- Improving soils, capturing water, changing the landscape
  - Soil conservation & rainwater harvesting – zai pits, contour bunds, half moons
  - Tree planting
  - Livestock intensification
- Social capital formation

Reij and Smaling, 2008

550,000 hectares of land rehabilitated

Green Wall of Sahel





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Terroirs côté Niger

19 km au nord de la frontière Niger-Nigeria

12 km au nord de la frontière Niger-Nigeria

8,5 km au nord de la frontière Niger-Nigeria

Terroirs côté Nigeria

1,5 km au sud de la frontière Niger-Nigeria

14,5 km au sud de la frontière Niger-Nigeria

38 km au sud de la frontière Niger-Nigeria

Figure 2 : Vue comparative de trois terroirs de part et d'autre de la frontière Niger-Nigeria

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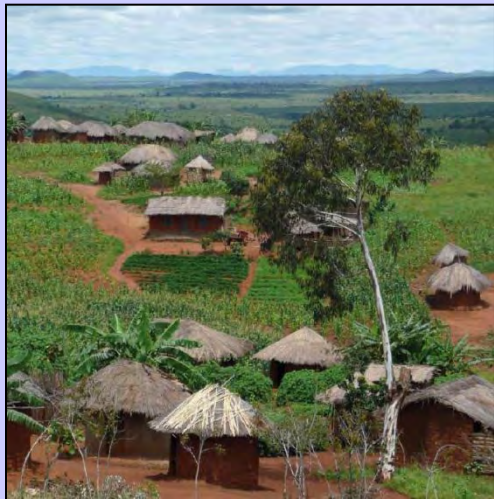
Fertilizer fallows E and S Africa

- Improved fallows with Sesbania, Tephrosia, pigeonpea, Crotolaria, Gliricidia
  - 2 years in fallow, then 3 years of maize

- Zambia yields
  - maize continuous for 5 years 4.8 t ha^{-1}
  - improved fallows (2 fallow, 3 maize) 8.5 t ha^{-1}

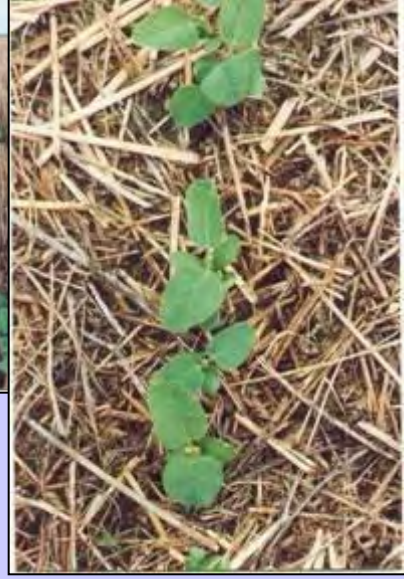
- Management intensive, farmer involvement in technology development, whole farm approach, use of organic and mineral fertilizers
  - Zambia – 65,000 farmers
  - Malawi – 42,000 farmers
  - Kenya – 15,000 farmers



- Malawi 345 farmers groups formed

Wambugu *et al*. 2010. IJAS

Conservation agriculture



- Conservation agriculture, min- or zero-tillage
  - Began Brazil & Argentina
  - GM soybean + herbicide use
  - Brazil – 25.5 M ha; Argentina – 19.7 M ha
- Benefits
  - better input use, water retention, increased organic matter in soils (& more carbon sequestration)
  - reduced erosion and water pollution
  - Yields up and more stable year on year
    - maize - from 3 to 5 t/ha (Brazil)
    - wheat - from 2 to 3.5 t/ha (Argentina)
- Zambia
  - Minimum tillage, legumes, mineral fertilizers and herbicides, crop residue retention, planting basins
  - Yields of maize up 50-100%; cotton up
  - 125-175,000 farmers
- CA estimates ~ 106 M ha worldwide

Kassam *et al*. 2009. *IJAS* 7 (4), 292-320

Legume intercrops Central America

- Velvet bean (*Mucuna pruriens*)
  - Multiple cropped with maize
  - 150 kg N fixed ha^{-1} yr^{-1}
  - 50-100 tonnes biomass ha^{-1} yr^{-1}
  - Improves and regenerates soils

- 45,000 families in Guatemala, Honduras & Nicaragua intercropping *mucuna*
  - Maize yields up
    - from 400-600 kg ha^{-1}
    - To 2000-2500 kg ha^{-1}

- Social capital critical
  - farmers' groups, experimentation, and extension

Catchment approach to soil and water conservation, Kenya

- Social processes
- Farmers' groups

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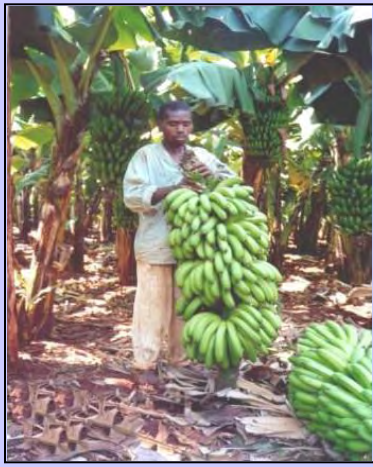
Crop improvements

- Local research highly effective
- Participatory
  - research, varietal testing and breeding
- Locally-developed plant and animal materials
- Focus on orphan crops
  - Cassava, plantain, orange fleshed sweet potatoes, tef, pigeonpea, soybean



Common lessons
Social infrastructure

- Social capital a prerequisite to impact and scaling up
  - Farmer Field Schools, cooperatives, Rural Resource Centres, business groups, Common Interest Groups, micro-credit groups, catchment groups

- Local research capacity highly effective
  - Participatory
  - Locally-developed plant materials and animals

- Increased knowledge leads to increased productivity
  - Farmers don't know everything – especially on pests & diseases

Common lessons
Social infrastructure

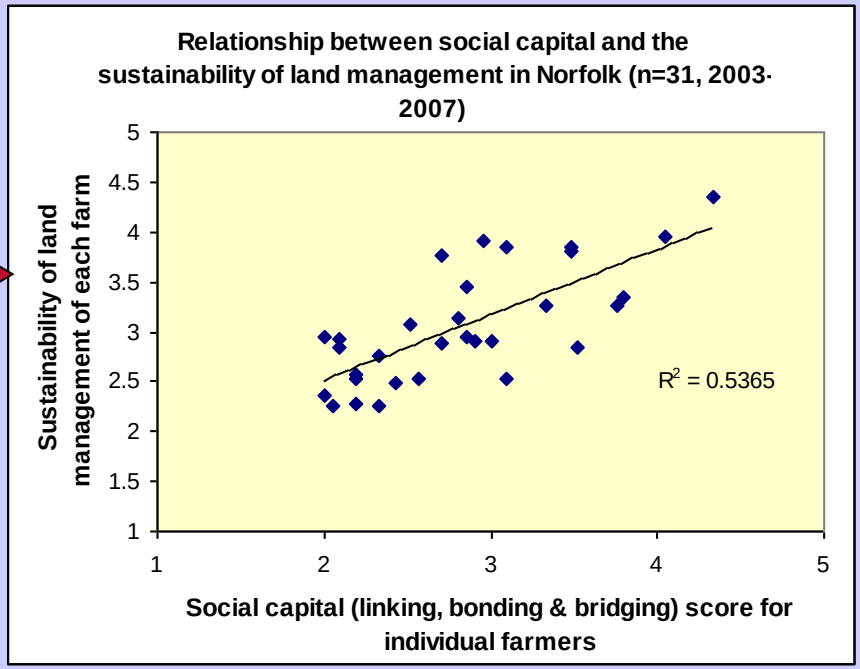
- Innovative co-learning and extension platforms
  - Videos
  - Mobile phones
  - Participatory plant breeding
  - Farmer field schools
  - Rural resource centres
  - Civil society campaigns

- Focus on women and children
  - Women' groups; food for children
    - Orange-fleshed sweet potato;
    - Milk
  - Business opportunities for women's groups
    - Cassava processing – Cameroon, Uganda
    - Vegetables

Social capital in UK farming

- 5 year trial (1999-2004): NALMI
- 31 farmers, 12,140 ha
    - 16 arable, 15 mixed
- Social capital and sustainability of land management
- Elements of social capital
    - Linking (engaging with those in authority)
    - Bonding (engaging with those with similar goals)
    - Bridging (engaging with those with different goals)

- Strong relationship between social capital and sustainability



- Sharp drop in linking social capital in past 40-50 years
  - Gradual distancing
  - Growing disrespect
  - Increasing divergence from government
- Loss of face-to-face contact from 1980s
  - Makes policy implementation harder
  - Slows transitions towards sustainability

1980s: 97% of comments about ADAS & "The Ministry" were positive

2000s: 87% of comments about govt agencies were strongly negative

Hall & Pretty, 2008, *Farm Manage.*

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Common lessons
Emergent private sectors

- Emergence of new private sectors
  - Aquaculture entrepreneurs
    - Business development driving economic growth
  - Private seed and input suppliers
    - Crops, trees & shrubs
  - Women's groups
- Novel partnerships (a form of social capital)
  - Private sector, NGOs, public sector, CSOs, farmers, banks
  - Create trust
  - Narrow-sense better than wide-sense (to avoid transaction costs)
  - New associations emerging
- New private sector partners
  - Ghana grains partnership
  - Unilever (Liptons) and smallholder tea growers

Common lessons
Enabling policy environments

- Incentives: Often needed to help establish social and technical infrastructure
  - WFP for Conservation Agriculture
  - Subsidies for fertilizers (eg Malawi)
  - Support for stone bunds, nursery trees, FFS

- Research, extension and incentives
  - Kenya NALEP
    - 20+ years of support to extension
    - 500,000 farmers reached per year
    - 7500 CIGs; many new enterprises
  - Malawi
    - Fertilizer subsidies
    - Surplus food production for country
    - Also 345 fertilizer fallows groups

Transformations are possible

Guatemala

Kenya

India

Thinking like a mountain

- Aldo Leopold – Sand County Almanac (1949)
  - Idea of the Land Ethic
    - ***"We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect..."***
- This century – a new opportunity to transform consumption behaviour and landscapes?
- And maintain biodiversity and economy?
- And reduce hunger?
- Whilst producing enough food for all?

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Thinking like a mountain

Transylvania, Romania

Priorities for 21st C For all countries

- More food from same land without harming supply of ecosystem services
  - And with growing constraints on resource inputs
- Improve investments in science and technology for both genetic and agro-ecological/agronomic outcomes
  - "Both-and" narratives
- Find ways to scale up "successes"
- Improve delivery and engagement mechanisms
  - Better partnerships between disciplines, agencies and sectors
  - Increase investment in agricultural research and extension
- Focus on developing innovative and adaptive agricultural systems for 21st C


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