Agricultural Engineering: Meeting the strategic challenges

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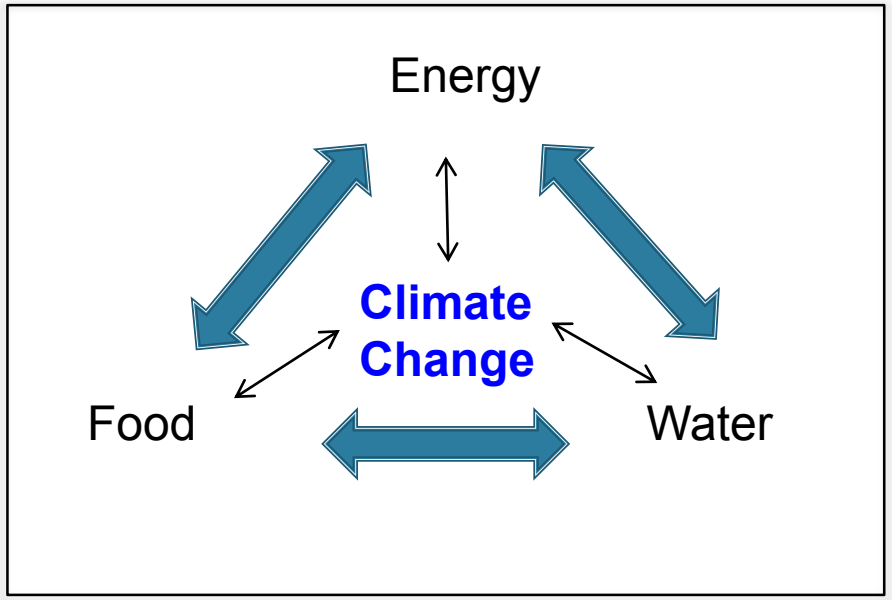
Summary

- Strategic challenges
- Problem
- Options and how engineering can enable them
- Making it happen

Global context

"The Perfect Storm"



Drivers
- Population
  - Food, water
  - Urban; more wealth
- Energy
- Climate Change

Pressures
- More intense use of land and water

State
- Land sealing
- Soil degradation
- Water resource degradation

Impact
- Less resources to support humanity and biodiversity

Responses
- Rational resource allocation
- Resource-use efficiency (HIGHER PRODUCTIVITY)
- Land and water restoration

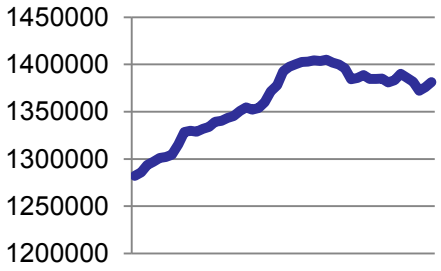
The challenge for agriculture

- Increasing demand for agricultural products makes it essential to increase production
- Constraints from competing urban demand for finite land and water resources

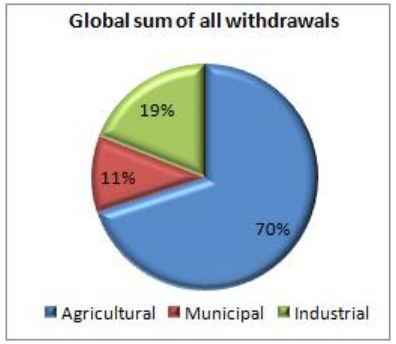
World Cereal Demand and Production

Period	Demand (Mt)	Production (Mt)	Demand growth (% y-1)	Production growth (% y-1)
1969/1971	1117	1118	2.0	1.9
1979/1981	1438	1442	1.6	1.5
1989/1991	1695	1732	1.3	1.2
2005/2007	2060	2068	1.3	1.2
2030	2719	2720	1.2*	1.2*
2050	3008	3009	0.9*	0.9*
* required annual growth rate from 2005/2007				

Global area of arable and permanent crops - 1961 to 2009 (10^3 hectares) (FAOSTAT)



Global water consumption (AQUASTAT - FAO)



Agriculture and climate change

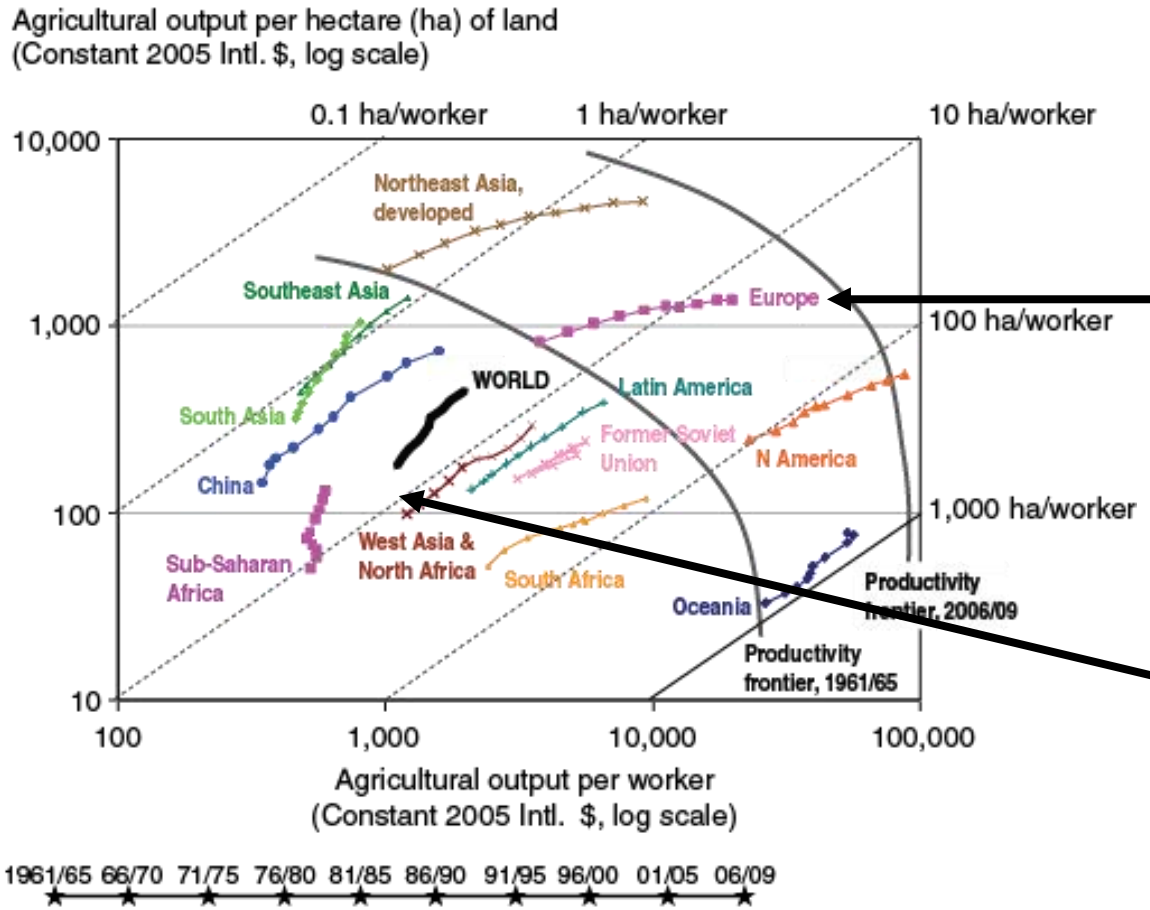
Mitigation

"Time is running out for agriculture to contribute to meeting global climate targets," World Bank Director of Agriculture and Environmental Services Juergen Voegele (April 22, 2014)

Adaptation

The 2014 IPCC report … predicts that climate change, without adaptation, will reduce yields for the world's major crops: wheat, rice and maize. Some projections predict yield losses of 25% by 2050.

GHG emissions from crops and livestock (Source FAOSTAT)	2011 Emissions Billion Tonnes CO2 equiv.	% Total emissions	% Increase 2001-2011
Enteric fermentation (livestock)		39	11
Synthetic fertilisers		13	37
Manure		23	
Rice paddies		10	
Burning grasslands		5	
Other (including e.g. diesel)		10	
Total	5.3	100	14



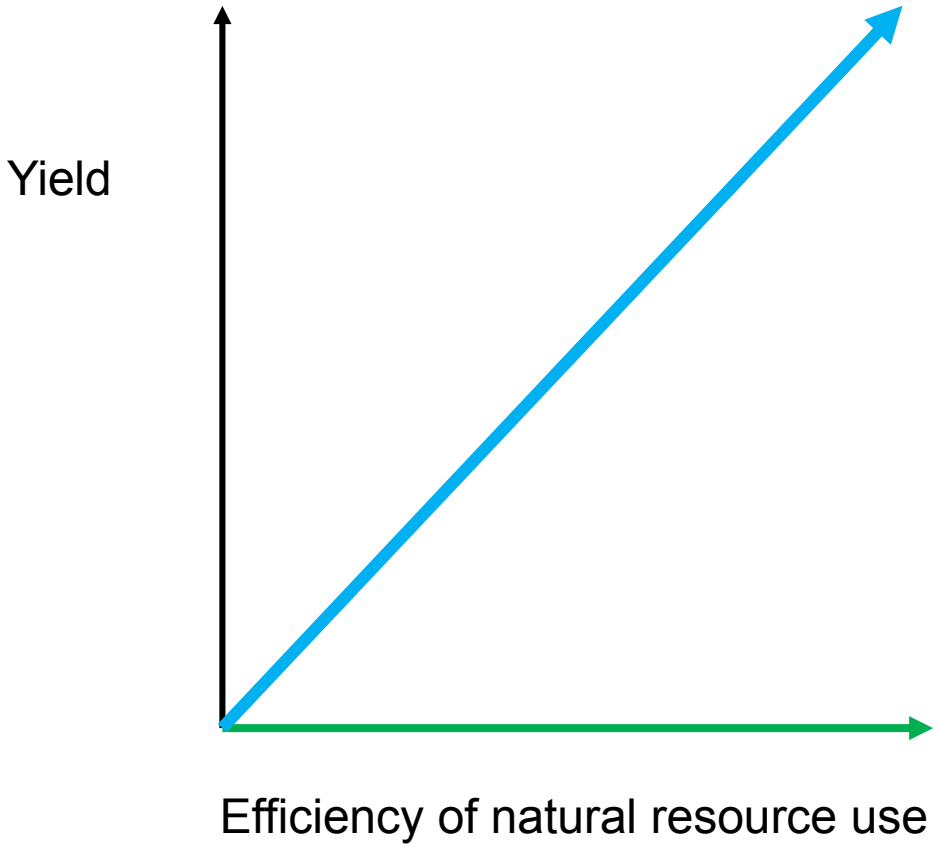
Agricultural output is the composite of 190 crop and animal commodities valued at constant 2005 international prices; agricultural land is total cropland and permanent pasture; agricultural labor is the number of economically active adults employed in agriculture. X and Y axis are in log values.

Source: Fuglie, Wang, and Ball (2012) using data from the Food and Agriculture Organization of the United Nations.

The rate of increase in yield is falling in Europe. How can it be increased?

Better deployment of existing technology in transitional and developing countries should deliver much higher global production. But will it?

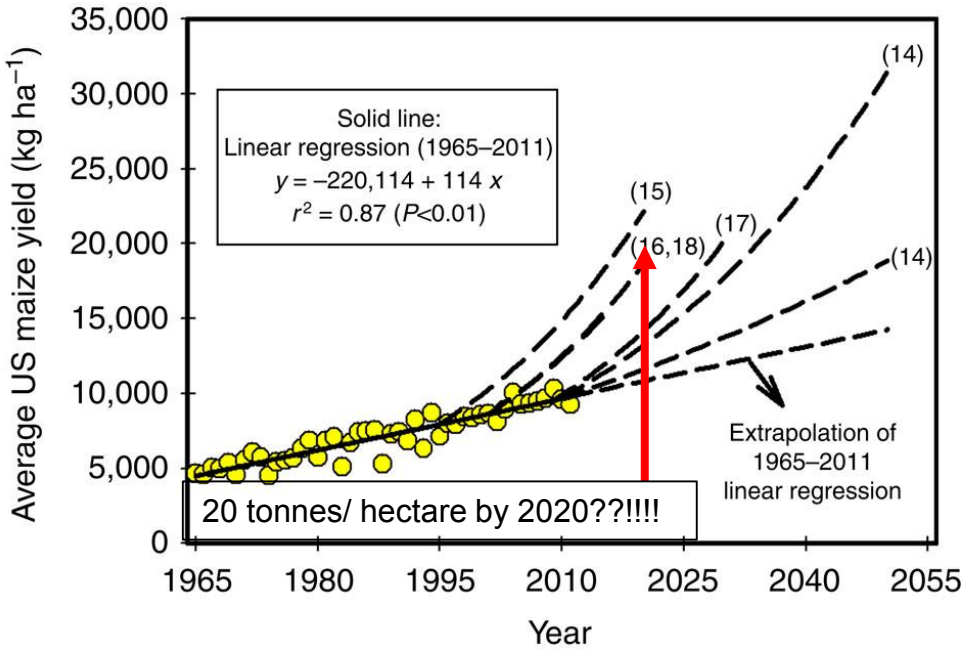
“Sustainable intensification”



- What are the strategic options?
- What are the engineering challenges?
- What knowledge infrastructure is needed to support rapid innovation?

How far will current agro-ecosystems take us?

Grassini et al., (2013) Nature Communications



A step-change in agricultural yields with reduced inputs and less environmental impact may require adoption of entirely New agro-ecosystems

Limitations of incremental improvement of existing systems

"The sustainability of the food production system is being questioned. Doubts are cast on the possibility to continue doing more of the same, that is, using high levels of external inputs in production, increasing the share of livestock in total output, expanding cultivated land and irrigation, and transporting products over long distances."

Alexandratos, N. and J. Bruinsma. 2012. ESA Working paper No. 12-03. Rome, FAO.

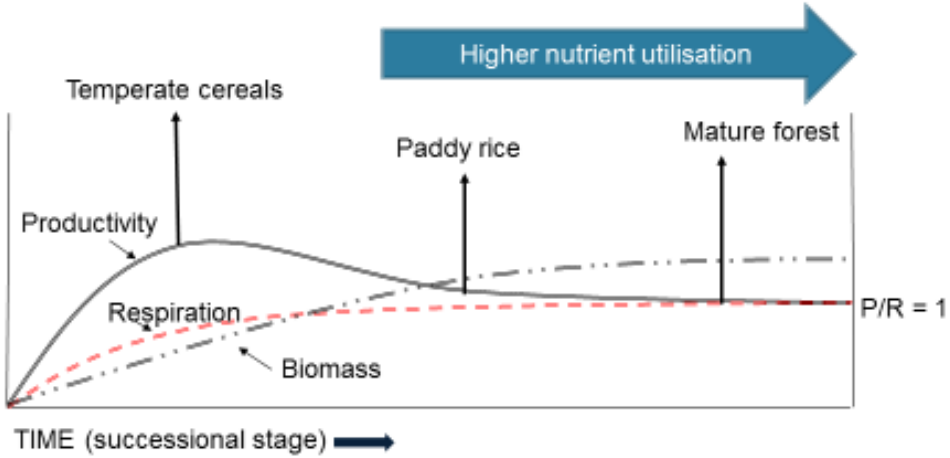
Issues beyond increasing yields:

- Reliance on a limited portfolio of crops, animals and systems
- Inherently leaky systems
- Current productivity depends on fossil fuels

Strategic options

Adapt and improve existing agro-ecosystems

Imagine and implement new agro-ecosystems



'The [ecological] strategy of "maximum protection" (that is, trying to achieve maximum support of complex biomass structure) often conflicts with man's goal of "maximum production" (trying to obtain the highest yield).' Odum, 1969

Engineering as the enabler for existing agro-ecosystems

Engineering challenges

- Optimisation via spatial-temporal targeting of operations to increase resource use efficiency (next generation precision agriculture using autonomous machines)
- Smart engineering that enhances natural resources e.g. irrigation; drainage; etc
- Precision root management, exploiting new soil and plant science
- Weed and pest control
  - Advanced mechanical weed removal
  - Targeted pesticide micro-application in place of macro-preventative spraying

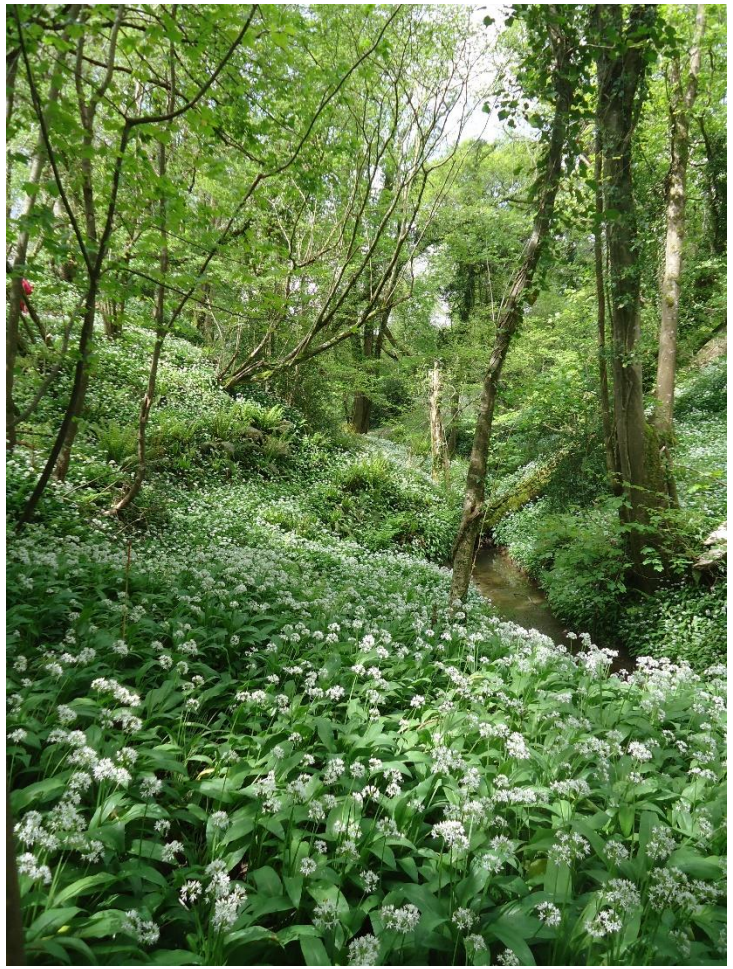
Imagining new agro-ecosystems

Possibilities

Later stage ecological succession for primary production and harvest several components (seeds, leaves, insects, animals)

Multicultural cropping: with small areas of different crops in a within-field patchwork rather than in large uniform fields in non-uniform landscapes.

Off-farm farming (JIT indoor salad crops; multi-storey goats; algae and fish)



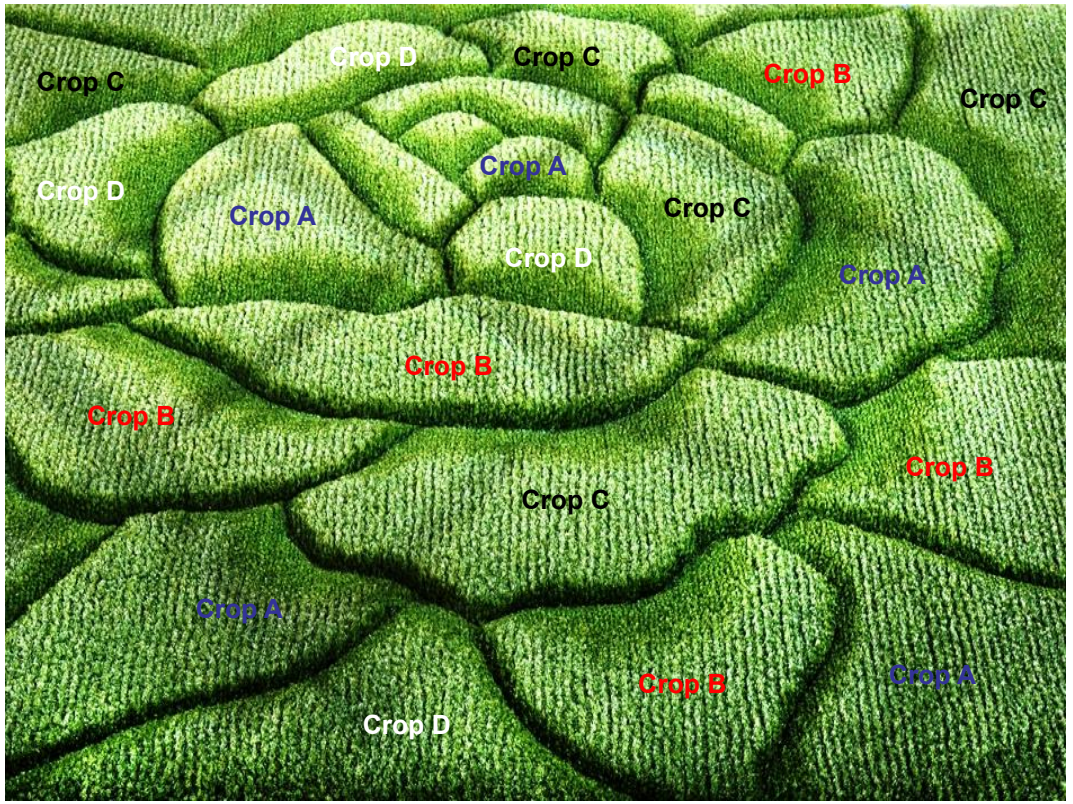
Engineering new agro-ecosystems

Engineering challenges

Mechanised establishment of complex field designs e.g. designing machines to sow a mosaic of different crops

Optimal application of nutrients and other inputs in a mixed crop system (remote and proximal sensors combined with robotics?)

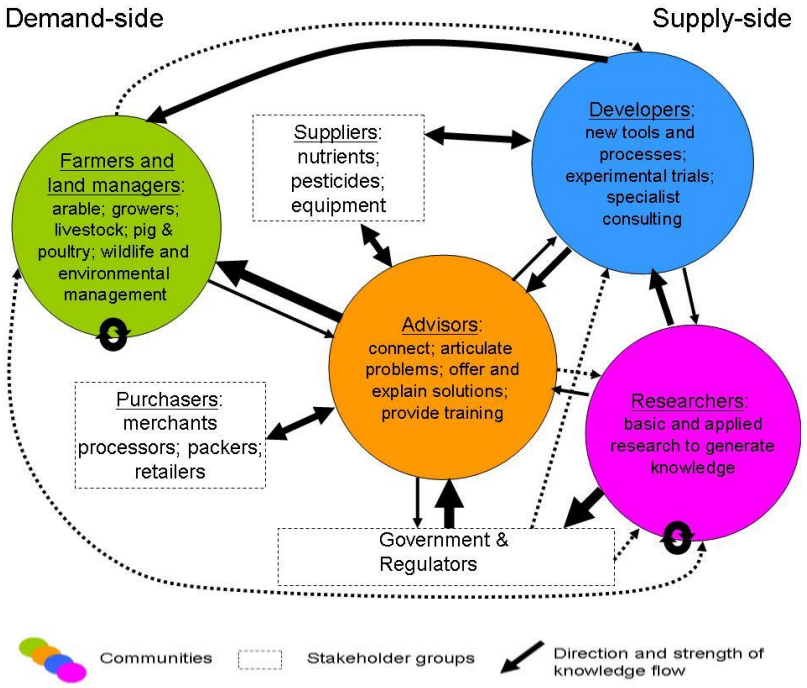
Harvesting in complex and non-uniform physical environments: designing machines able to harvest and potentially sort mixed crops



Making it happen

- Creating space to imagine a different agriculture
- Public investment in a ‘Manhattan’ scale project for agricultural production to achieve a technological step-change in food production
- Development of existing agro-ecosystems, driven by problems transforming technology developed in other sectors

More investment is needed in developers



Kibblewhite, Deeks and Clarke (2010)

Thank you

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