Re-Imagining agriculture; Engineering as the strategic enabler

Professor Mark Kibblewhite

An introduction

- Background
- Objectives for the conference
- A little theory
- Novel agro-ecosystems
  - *Some ideas*
- Engineering challenges

RE-IMAGINING is to dream up; conceive; conceptualize; create; devise; envisage; envision; fantasize; frame; invent; picture; plan; project; realize; scheme; spark; conjure up; think up; vision

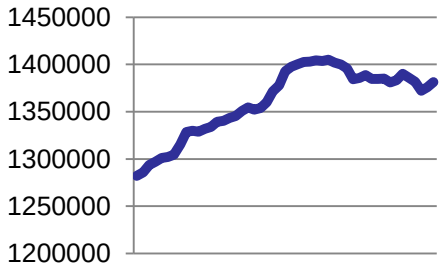
The challenge for agriculture

- Increasing demand for agricultural products makes it imperative to increase production
- Competing urban demand for finite land and water resources means agricultural productivity must increase sharply

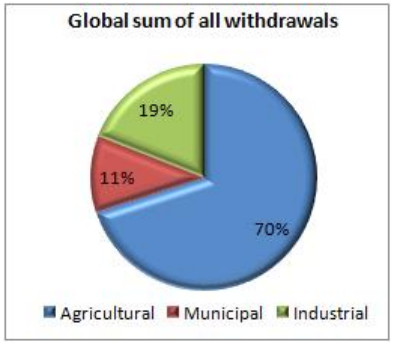
World Cereal Demand and Production

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				

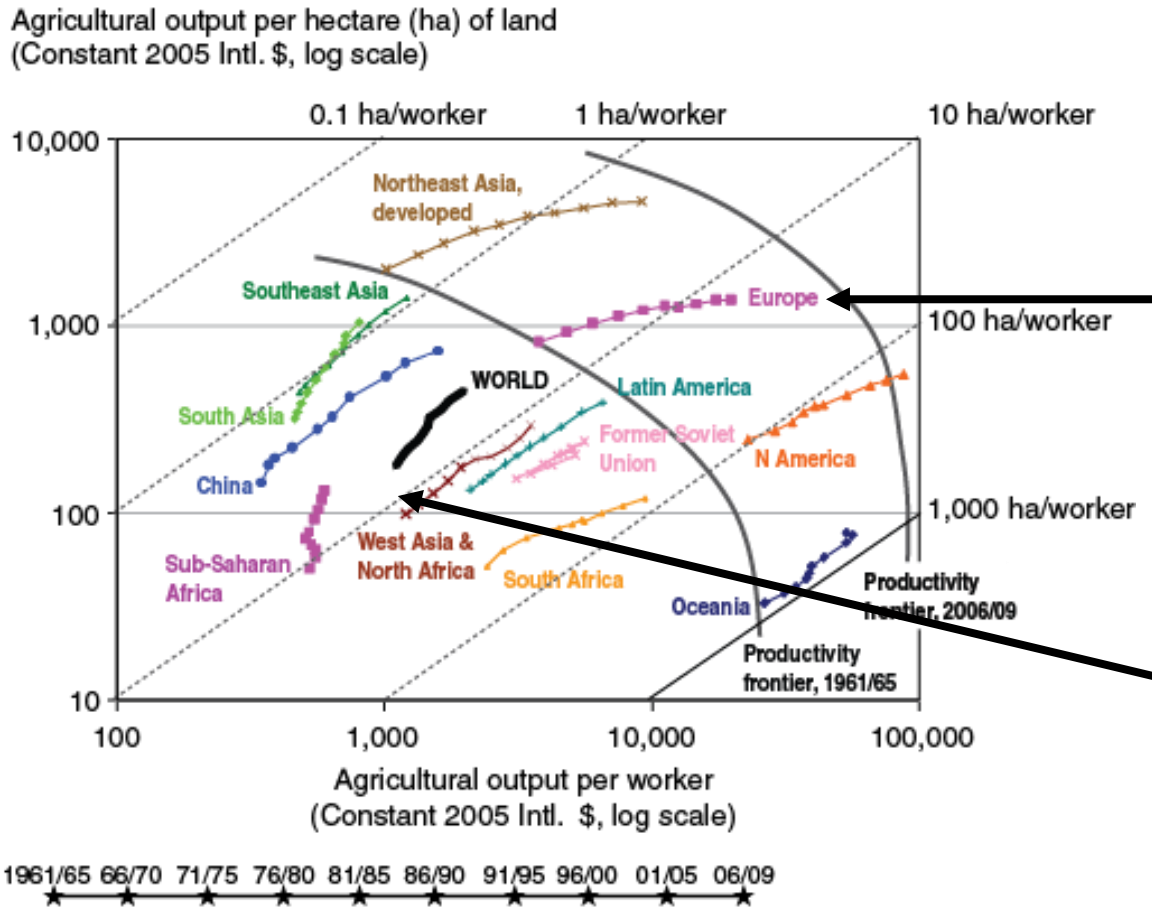
Global area of arable and permanent crops - 1961 to 2009 (10^3 hectares) (FAOSTAT)



Global water consumption (AQUASTAT - FAO)



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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?

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)

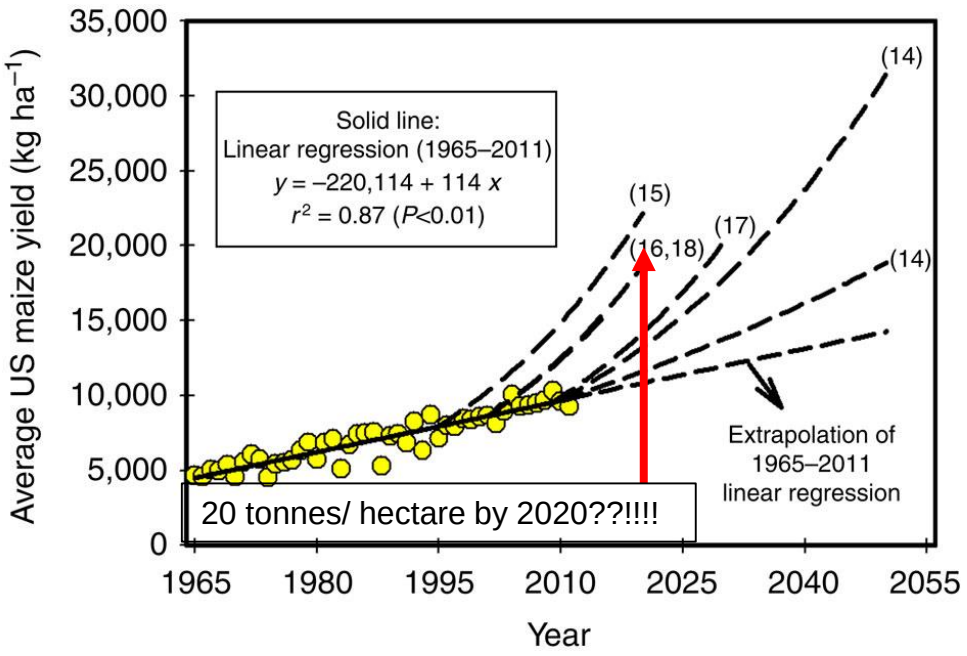
Adaptation

"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." Lynne Featherstone MP, DFiD Minister, 3 April 2014

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

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 requires a system change

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 higher yields:

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

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Challenges to researchers

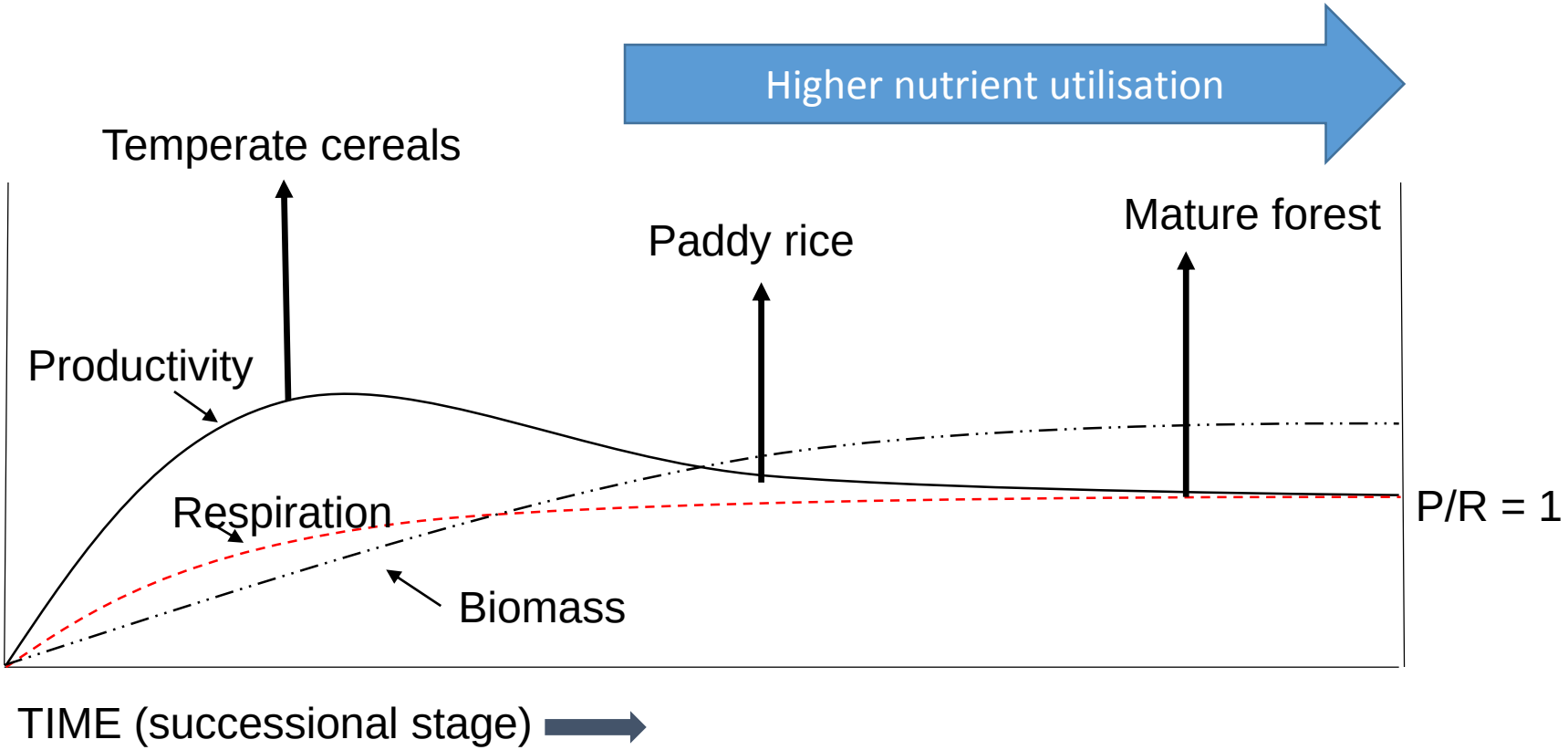
A UK strategy for agricultural technologies, HM Government, 2013:

"[More productive agriculture] will need multiple approaches. Adapting existing farming techniques, developing entirely new production systems [and] innovative engineering…."

- Can a technology step change in productivity be achieved?
- Might there be highly productive novel agro-ecosystems that could be developed and exploited successfully?
- Can we identify options that are
  - **Are substantially more productive?**
  - **Technologically feasible?**
  - **Commercially viable?**

Objectives for the conference

- Explore options for novel agro-ecosystems that could perform better than the existing ones
- Identify the agricultural engineering challenges that have to be met to adopt these novel agro-ecosystems commercially
- Create momentum and a network to refine ideas, develop options and take them forward in to practice



'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

Some possible options

Move to a different stage of ecological succession for primary production

- Why not harvest solar energy, grow algae and process these in to food and fuel? Or move to a more mature ecology and exploit diversity better - Permaculture v2? Insects? Rodents?

Optimise growing areas?

- Adopt small areas in a within-field patchwork rather than uniform fields in non-uniform landscapes? Which scale is optimal for which landscapes and systems?

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

- Higher productivity (including less waste in the downstream food chain); opportunities for energy and resource recover; just-in-time harvesting.

Some ‘odd’ questions

- Are our preferences for particular agro-ecosystems more determined by culture than science and objective analysis?
  - **Is tillage essential or a just tradition?**
  - **When is a weed not a weed?**
  - **Are animals a luxury we cannot afford or are they essential to efficient agriculture?**
  - **Why don’t we eat more insects, fungi and rodents?**

Some reflections on field design

- Field designs have evolved only a little since the 1800's - The field is adapted to the machine rather than the machine to the field
- It might be better to design a field that maximises ecological performance and then create new machines to make it operationally feasible? It should be better to adapt the machine to the best field design rather than the field to the machine
- What would these fields look like and what sort of machines might be needed?

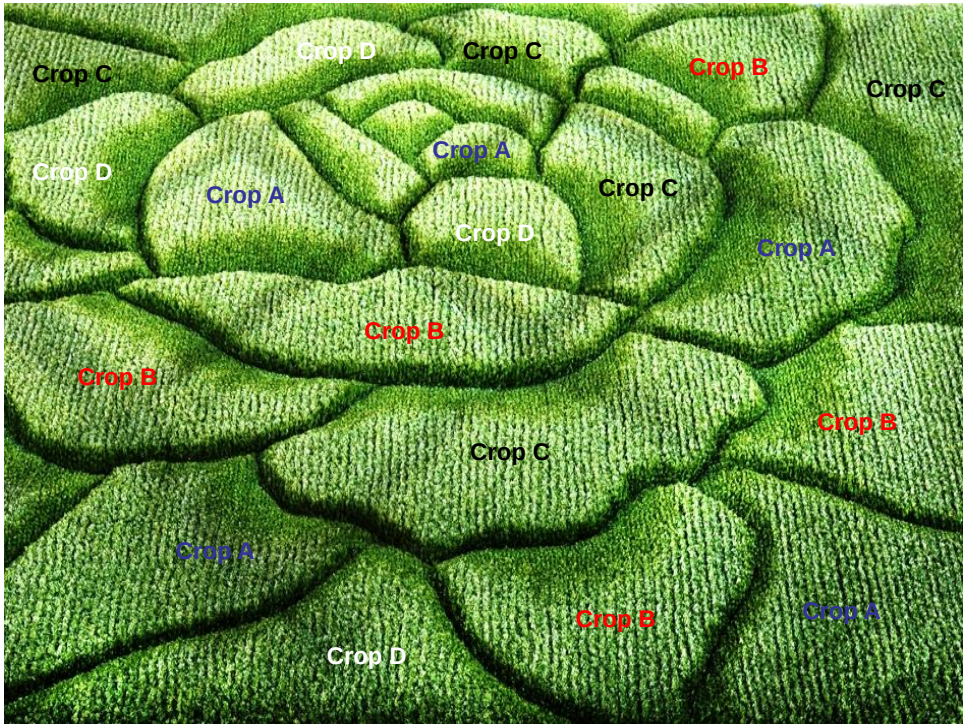


Malcolm Morley

Current field layouts evolved from those suited to horse teams and early mechanisation. They have single crops in straight rows. Are there more productive and resource efficient ones?

Research challenges to novel field design implementation

- Identifying compatible crops
- Measuring soil and other properties to predict optimal field patterning
- Designing machines to sow a mosaic of different crops simultaneously
- Understanding how to optimise and apply nutrients and other inputs in a mixed crop field system (remote and proximal sensors combined with agribots?)
- Designing machines able to harvest and potentially sort mixed crops



A field design with carefully positioned patches of different crops could be higher yielding and both more resource-efficient and resilient to pests and disease

Exciting Engineering Challenges

- Ultra-precision agriculture – plant by plant
- Setting up and harvesting non-linear field layouts
- Dispersed animal management
- Post-harvest product separation
- Off-farm systems



Polydome is a concept for a new kind of polyculture greenhouse that achieves very high yields by strategically interweaving crops and livestock. With its diverse outputs (over 50 crops, two mushroom varieties, chickens, eggs, fish, and honey), even a small Polydome system can provide a richly varied food supply for a large population.

http://www.doorsofperception.com/food-systems-design/the-high-tech-permaculture-metabolic-engine-greenhouse/#sthash.xrmZQK1e.dpuf