Putting the Bio into BioFuels

Douglas B. Kell

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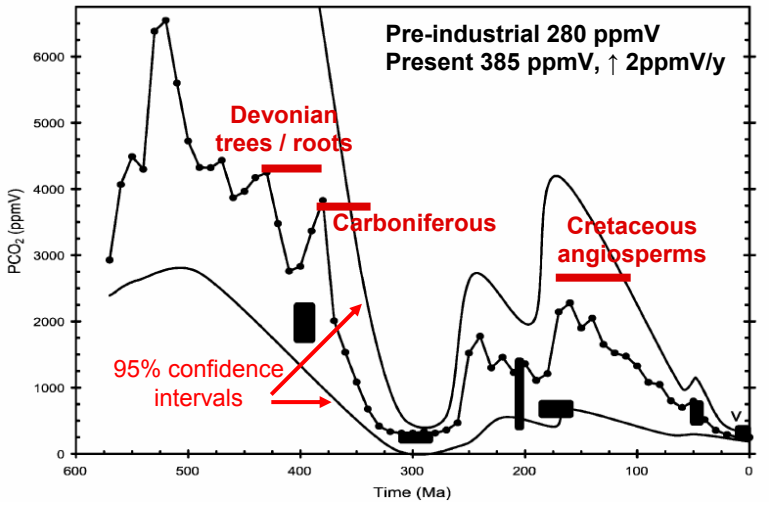
Foundation for Science and Technology Discussion,
***Is there a viable future for biofuels in the UK*?**
April 6th, 2011

Summary of the talk

- History of biomass and C-sequestration
- Available UK land area and present yields
- Potential yield improvement and science drivers
- Examples of present research
- Plant-derived Biofuels and Carbon sequestration; a win-win strategy requiring development

Atmospheric CO_2, plants and carbon sequestration over geological time



Royer et al. (2001) Earth-Sci Rev 54, 349–392

What biofuel crops for the UK?

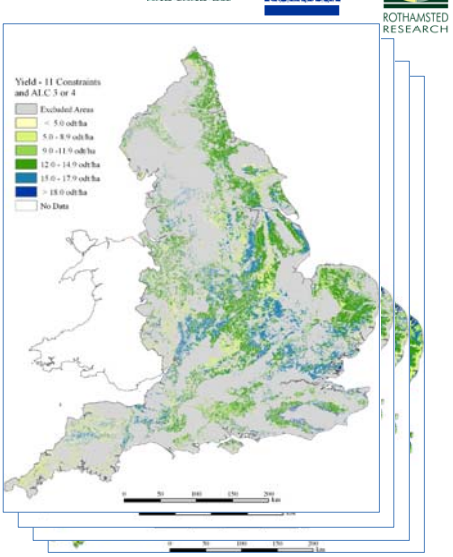
- 1% of world land area, but leading nation in plant sciences and agricultural research
- Multiple feedstocks / multiple products
  - Waste in many forms
  - Dual food/fuel crops e.g. cereals/straw, sugar beet
  - Short-rotation coppice (SRC) Willow
  - *Miscanthus* x *gigantea* grass

Land Use Challenge (*Miscanthus*)

- Yield map England for all soils except organic (~ 10 M ha) (whole UK 25M ha)
- Yield map for 9 (primary) constraints (<8 M ha)
- Yield map for 11 (secondary) constraints (<5 M ha)
- Yield map for ALC 3&4 (~7.4M ha total, ~ 3.1 M ha after constraints)

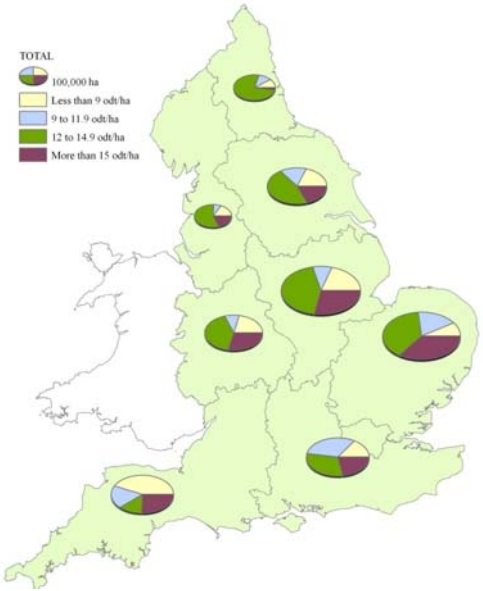
http://www.relu-biomass.org.uk/
http://www.tsec-biosys.ac.uk/

Slide courtesy Angela Karp, RRes



Lovett et al. (2009) BioEnergy Research 2:17-28

Regional challenge



Regional contrasts occur

Areas with highest yields co-locate with important food areas

When high value land and grassland are avoided , scenario of 350,000 ha (Renewable Obligation) displaces

- 102,939 ha of winter wheat (5.5 % of nationally planted area)
- 26,799 ha of oilseed rape (5.9%)

(Total yield of 4.6 MT translates to ~6.5 M MWh of electricity (2.4%))

UK forests 12% land area, cf..Germany/Italy 30%, Sweden/Denmark 65%

Assumes 12.5 odt/ha but should assume 15-22 odt/ha by 2050

Slide courtesy Angela Karp, RRes

Lovett, A.. et al. (2009) BioEnergy Research 2:17-28

Bioenergy → liquid fuels in particular

- Liquid fuels energy density vs batteries (note potential of fuel cells)
- Liquid transport fuel infrastructure exists (though there are issues wrt engine modifications)
- Ethanol commonest, albeit a poor fuel re C:H:O ratio
- Bio-butanol being considered
- Hydrocarbons via pyrolysis or algae

The importance of yield per hectare

- Theoretical photosynthetic yield is 5% (C_3 plants) – 7% (C_4 plants)
- Present yields of plants wrt light input are typically 1% (insolation 0.1 – 1 $kW.m^{-2}$)
- Losses mainly from 'dark reactions'
- Increasing yield per ha the key issue. No one thing limits, including thermodynamics
- Yields over time for grains ~ 1-3%↑$.y^{-1}$

There are incomparable science drivers

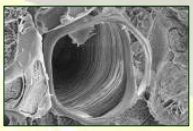
- Variation typically 5-15 $t.ha^{-1}$, part genetic part agronomic
- Genomics-driven breeding a key – sequencing now does in one week on one machine what took all of history to Jan 2009 (200,000,000,000 bases)
- Need for multiple cultivars and traits, including ease of breakdown (especially lignin)
- Disease and drought resistance

BSBEC trial planted at Aberystwyth and RRes

Biofuels pipeline

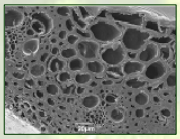
BBSRC Sustainable Bioenergy Centre

BBSRC bioscience for the future



Biomass Growth

Biomass Composition



Biomass Deconstruction

Fermentation

Fuel

Sustainability Analysis

BBSRC bioscience for the future

Examples from the BBSRC sustainable Bioenergy Consortium (BSBEC)

- Novel Enzymes from marine wood borers ('gribbles')
- Bio-butanol
- Modification of plant cell walls
- Does not yet include 3rd generation biofuels e.g. algal oil generation via synthetic biology

Biofuels are a subset of Industrial Biotechnology post-Fossil Fuels

- As oil and coal disappear not only will transport fuels but all other organic chemicals will have to come from modern photosynthesis
- The Knowledge-Based BioEconomy
- Need to consider integrated biorefineries along with logistics; today I am mainly looking at primary fixation of CO_2 - which also includes sequestration

Contribution of bioenergy crops

Predicted soil emissions/ sequestration (tCO_2ha^{-1} p.a.) : annualized 20-year av. RothC.

Hillier et al (2009) GCB 1; 267-281

- Higher gains from perennial biomass crops
- Most important factor affecting GHG gains achievable (of biomass crops) is final product yield
- Big knowledge gap on effects of biomass crops on soil carbon stocks

http://www.tsec-biosys.ac.uk/

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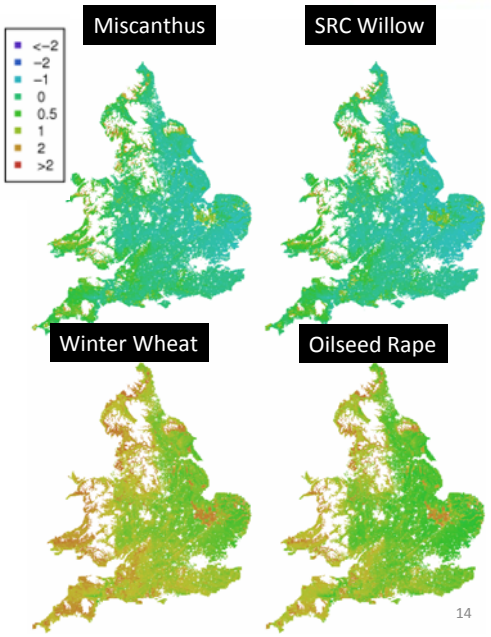
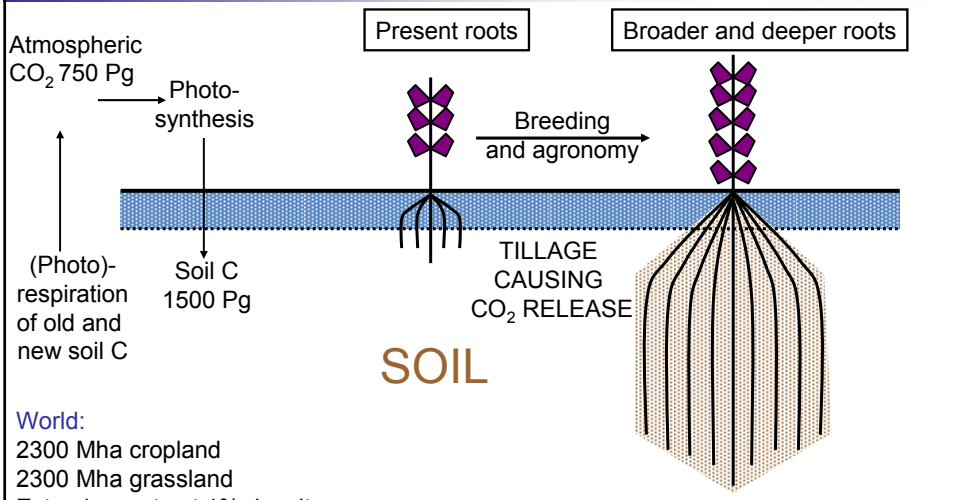
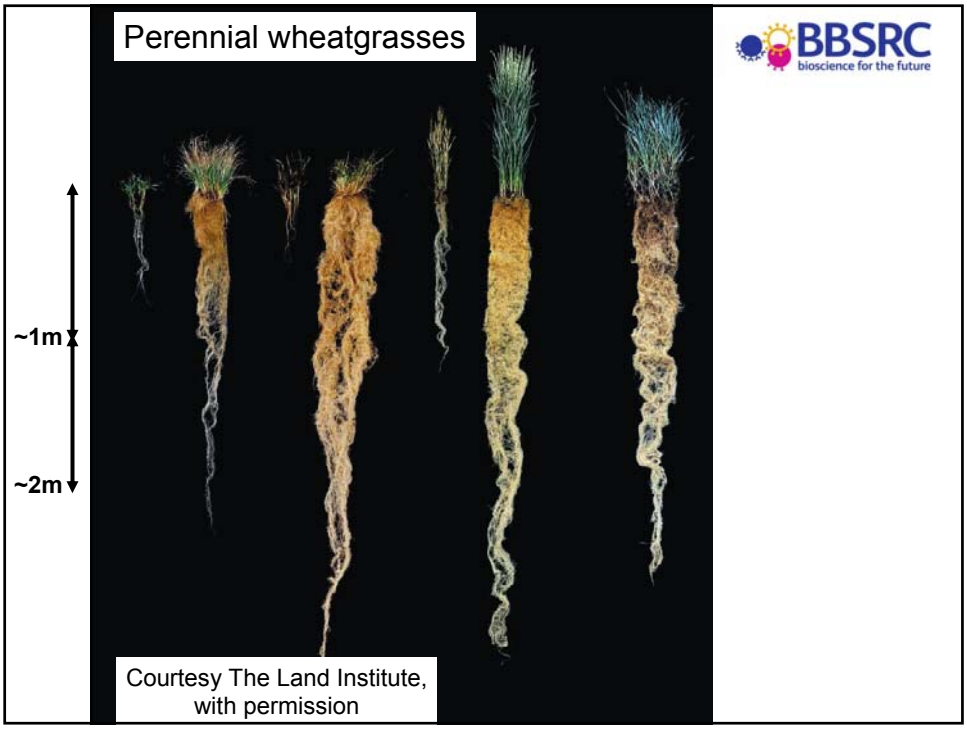


ATMOSPHERE



World:
2300 Mha cropland
2300 Mha grassland
Extra 1m roots at 1% density = 100 $t.ha^{-1}$ C sequestered; if 2y lifetime → 50 $t.ha^{-1}$.
Removes 118 ppmV CO_2 from atmosphere

Much greater steady-state trapping of C, and also of nutrients and water, leading to improved drought- and flooding tolerance, greater biomass yields, and better soil structure and steady-state C sequestration



Concluding remarks

- Significant role for biofuels in UK
- Major need and opportunities for improving yields and other traits
- Carbon sequestration in soil can go hand in hand with improved above-ground biomass production.
- Policy drivers for biofuels. How to incentivise farmers to plant these crops? Carbon credit payments?

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