Developing sustainable farming systems by valuing ecosystem services

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Rothamsted research
What is sustainability?

Profit or environmental cost (£/ha)

Sustainability gap
Quantifying sustainability

- Common unit needed. Used a financial assessment to begin with based on Total Factor Productivity (TFP)
- Includes both business and environmental costs
- Used to analyse the overall sustainability of wheat on Broadbalk and several different commodities from ‘real’ farming systems
Total Factor Productivity (TFP)

- Ratio of Outputs to Costs in common units, i.e. £ or euro
- There may be multiple outputs (straw, grain, wool, meat, milk, etc.)
- Costs include environmental costs, i.e. externalities
- TFP>1 implies sustainability

Data sources for commodities

- **Life Cycle Analyses**
  Williams et al Report to Defra, 2006

- **Agricultural Almanacs for economic data**
  Nix, 2005

- **Environmental burdens of nutrients, GHG, Sprays**

- **Land valuation through Ecosystem Services (ES)**
  Costanza et al., Nature, 1997

- **Computer simulation models and tools:**
  SUNDIAL, WDM, Quad-Mod
Wheat and oilseed rape, 2006 data

Yield response

wheat

Total costs £ ha\(^{-1}\)

Includes environmental costs

osr

Total costs £ ha\(^{-1}\)
Breakdown of environmental costs and burdens for arable crops

Winter wheat

OSR
Beef and sheep farming

Grazed 18 month Beef

3 month finishing grazed lambs
Breakdown of environmental costs and burdens for livestock systems

Grazed 18 month beef

<table>
<thead>
<tr>
<th>N applied to sward kg ha</th>
<th>Environmental costs £ kg⁻¹</th>
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</thead>
<tbody>
<tr>
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3 month finishing grazed lambs

<table>
<thead>
<tr>
<th>N applied to sward ha⁻¹</th>
<th>Environmental costs £ kg⁻¹</th>
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<td>120</td>
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Extensification vs Intensification

Land Sharing vs Land Sparing

- Extensification reduces inputs, emissions and yields
- Needs more land
- Intensification increases yield, inputs and emissions?
- Needs less land
Some ‘Win-Win’s’

Broadbalk: mean yields of wheat grain, cultivars and major changes

- Fallowing
- Liming
- Herbicides
- Fungicides
- Modern cultivars
- 1st wheat, FYM+N3
- 1st wheat, Best NPK
- Cont. wheat, N3PK
- Cont. wheat, FYM
- Continuous wheat, unmanured

Grain, t/ha at 85% dry matter

Introduction of modern dwarf cultivars
Total Factor Productivity

Broadbalk Continuous Wheat experiment

TFP (Profitable if > 1)


Broadbalk, Plot 8

Broadbalk, Plot 8, minus area payments
Broadbalk yields and TFP, 1870 - 2000

TFP

Grain yield, t/ha
85% DM
Win-Win: Breeding for yield brings environmental benefits?

Additional 0.8 t/ha yield and up to 5 mg/l less nitrate from the new variety.
Win-Win-Win...:
Benefits of soil organic matter/carbon

Increasing soil organic carbon benefits yield as well as to water storage, soil biodiversity...

SOC:
FYM since 1852
SOC: 3.5%
Fertilisers since 1852
SOC: 1.4%
Moving the threshold: Olsen P required for 95% yield at two SOC levels

Johnston et al., 2009, Advances in Agronomy 101, 1-57.
Draught force and SOC in the Broadbalk winter wheat experiment

Watts et al., 2006, Soil Use & Management 22, 334-341.
Possibility Frontier

Current bounds of what is technically possible
Tradeoffs an issue for policy
Inefficient region
Improve by extension

Pushing the envelope. Research
Key factors in sustainability

- Resilience, particularly economic (prices, yields)
- Ecosystem Services – will farmers be paid for more than yield?
- Stability, i.e. minimal variation (effective control of pests and diseases; mitigating climate change)
Acknowledgements

Some of this research was funded by the UK Biotechnology and Biological Sciences Research Council (BBSRC)...

...and some by the UK Department for Environment, Food and Rural Affairs.
Research can move the possibility frontier.
Moving towards sustainability

Profit or environmental cost (£/ha)

- **Sustainability benefit**

Legend:
- Profit
- ES Wheat
- Sprays
- Nutrients (N,P)
- N2O
- CO2
- ES Lost
Pigs and broiler production

Outdoor pigs

<table>
<thead>
<tr>
<th>Total costs £ ha⁻¹</th>
<th>TFP</th>
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<td>18000</td>
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Sales £ ha⁻¹

12 sows/ha  18  25

Conventional  Free Range  Organic

Poultry

<table>
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<th>Total costs £ tonne⁻¹</th>
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Sales £ tonne⁻¹

Conventional  Free Range  Organic