Integrating bio-diversity effects in the whole system's analysis - optimizing land use for the bio-economy

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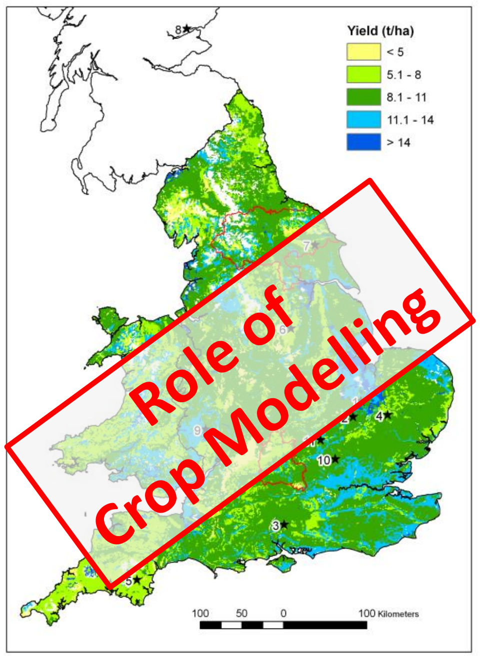
Outline

- Background and key challenges
- LCA – attributional vs. consequential approach
- Process-based models (steady state assumptions)
- Integrate ecosystem services (biodiversity)
- Implement policy (biodiversity at landscape scale)

Steady state yield map application

www.tsec-biosys.ac.uk



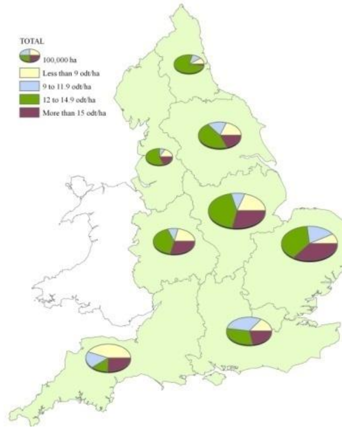
Richter et al., *Soil Use Manage* **24**, 235 (2008)

Hillier et al., *Global Change Biology – Bioenergy 1*, 267 -281(2009)

Aide to Producers & LUC planners

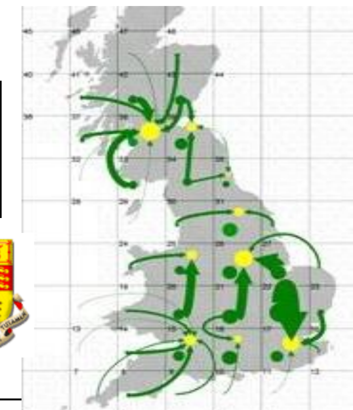
Lovett et al. BioEnergy Res (2009)

BE Allocation Constraints & Trade-offs

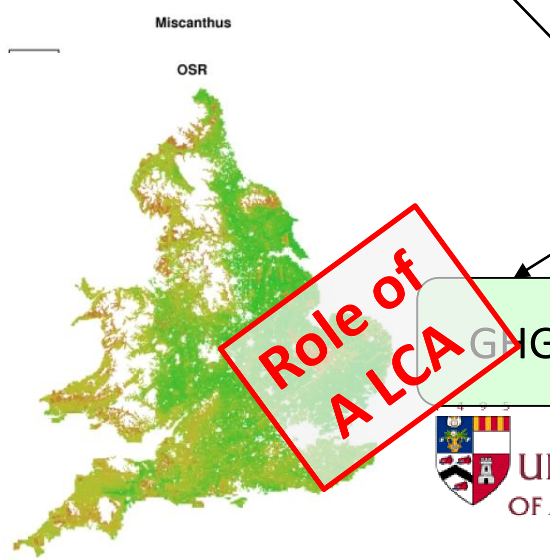


Economy of BE Supply & Demand

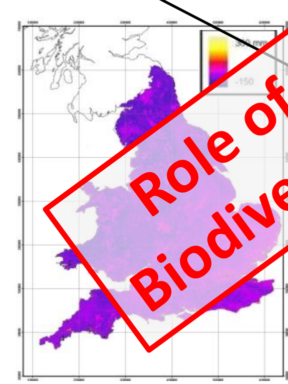
Bauen et al. *BioResource Tech* (2010)



Ecosystem Services



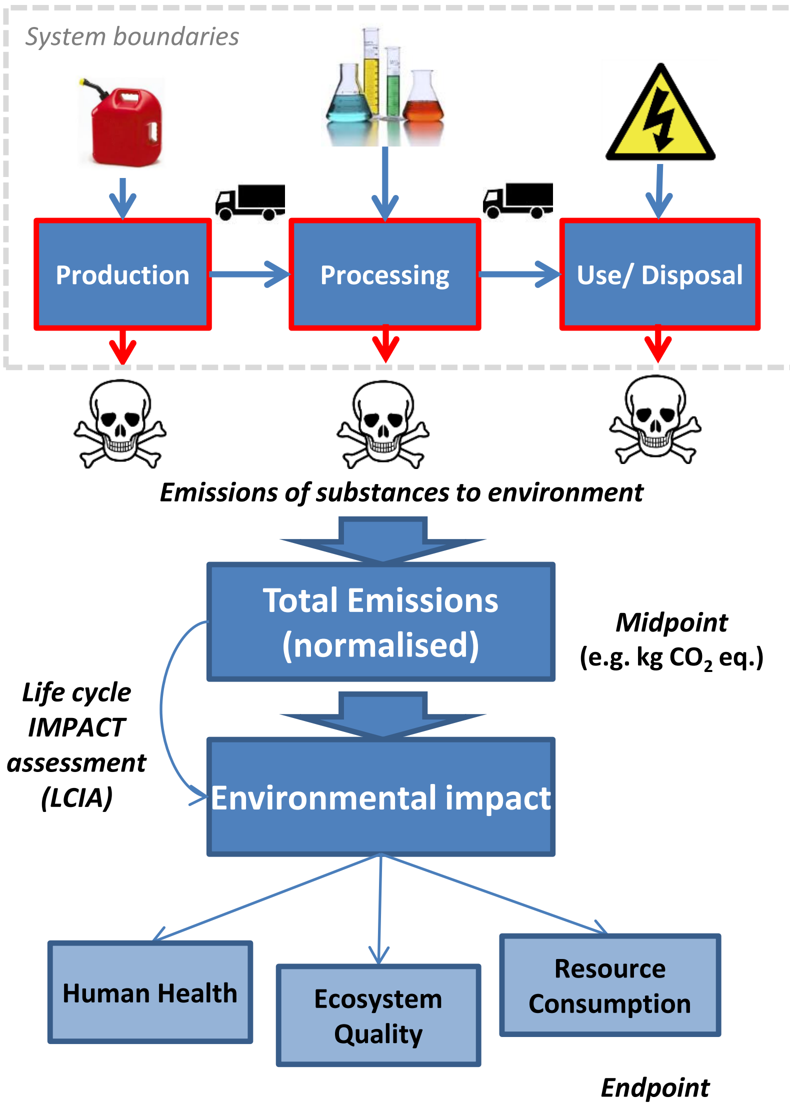
GHG



H_2O

TSEC Biosys

Life cycle assessment: Methodological challenges



- 'Cradle to grave' assessment of all related emissions accounted to:
  - Product or service
  - Sector

Midpoint – provides a normalised number

Good for comparisons, but doesn't say much about the impact

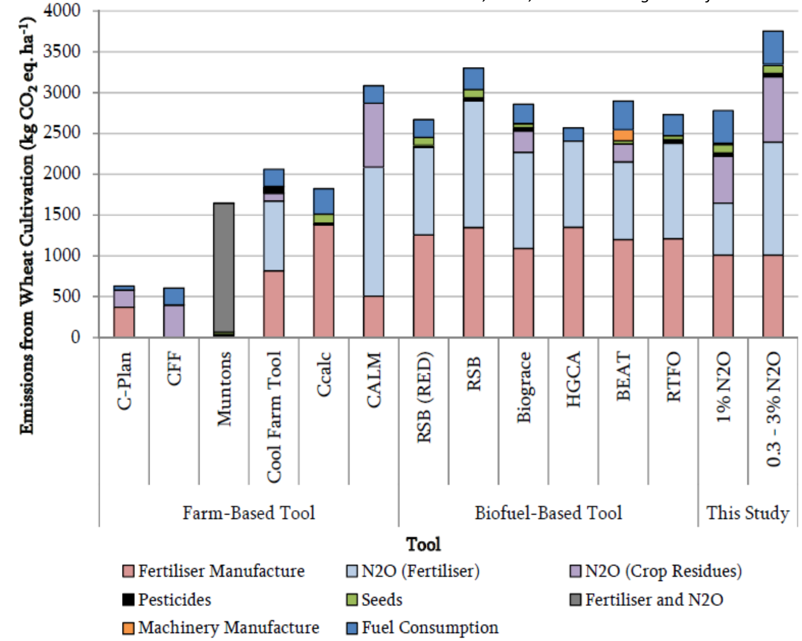
Endpoint – explains impact on environment via mechanisms/models

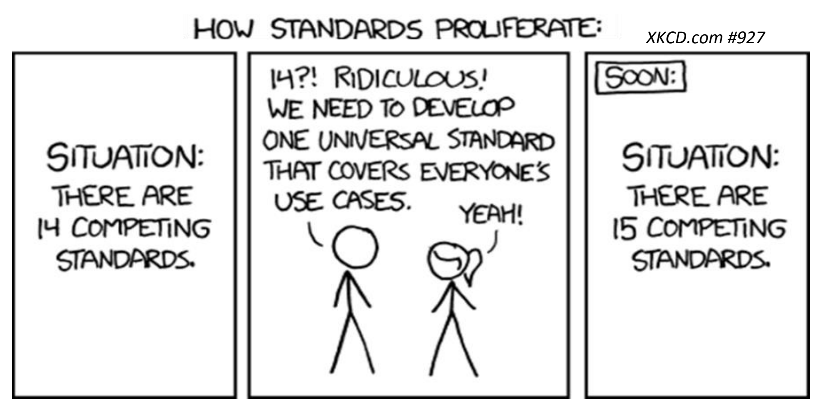
Increases uncertainty, but also increases usefulness to policy makers

LCA: Midpoint challenge

- **Midpoint: GHG reporting**
  - ISO Standards are flexible
  - Methodologies exist to 'harmonise' calculations
    - Specify system boundaries and allocation rules
  - Different methodologies have large impacts on the results
  - 'Midpoint' does not necessarily mean a simple approach

Whittaker et al., 2013, Env. Modelling and Software

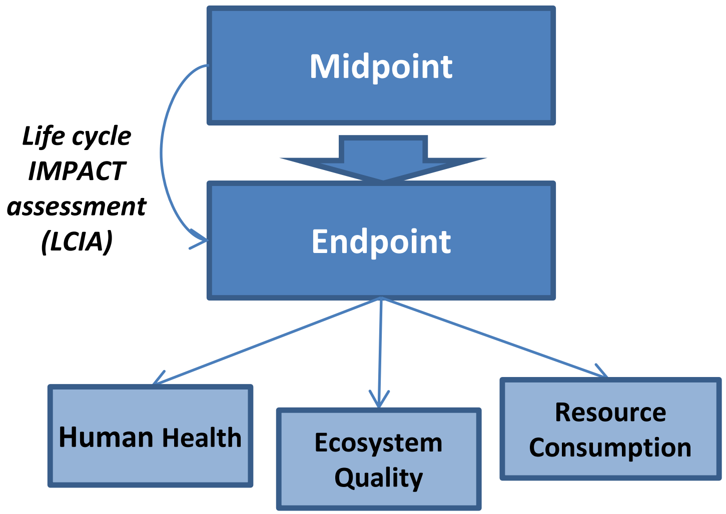




XKCD.com #927

LCA: Biodiversity

- **Biodiversity** will also have host of methodological issues



Midpoint: Various metrics exist (Potentially Disappeared Fraction *PDF, α*-diversity, Ecosystem scarcity)

- Methodological biases
- Exceptions to the rule

Endpoint: Various methods of LCIA

- Ecosystem service loss
- Lots of data/assumptions required

Once you've picked your method you still must address:

Temporal & spatial challenges

How to make comparisons?

What are the baselines?

What question are we asking?

“Attributional” vs. “Consequential” LCA Approaches

Framing your question

> What are the environmental impacts of producing 1 litre of bioethanol from wheat?

Spot the difference

> What are the environmental impacts of producing bioethanol from wheat?

Attributional LCA

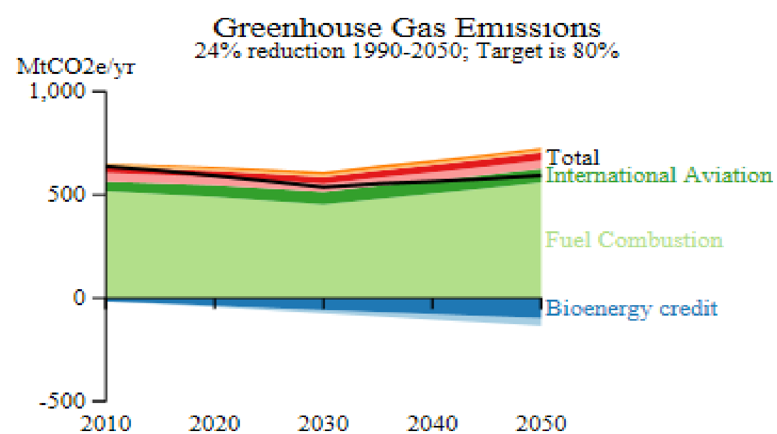
- Looks at a single unit of production
- Provides a snap shot of impacts
- **Attributes responsibility of emissions**

Consequential LCA

- Looks at knock on effects
- Considers changes in production levels
- **Considers interactions between markets**

Specific supply chains = Regulation

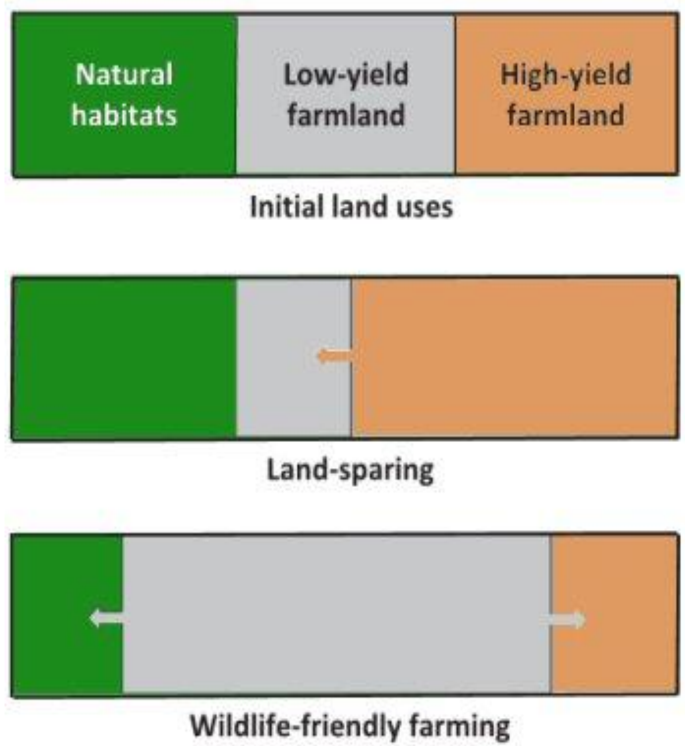
Networks/Markets = Policy analysis



Thinking about the whole farm

E.g. Conservation approaches: Land sparing or **sharing**?

“Sharing” instead of intensification has been shown to benefit conservation (Lamb et al., Nature Climate Change Letters 2016)



Intensification

Reduces impacts (ALCA) due to improved yields etc.

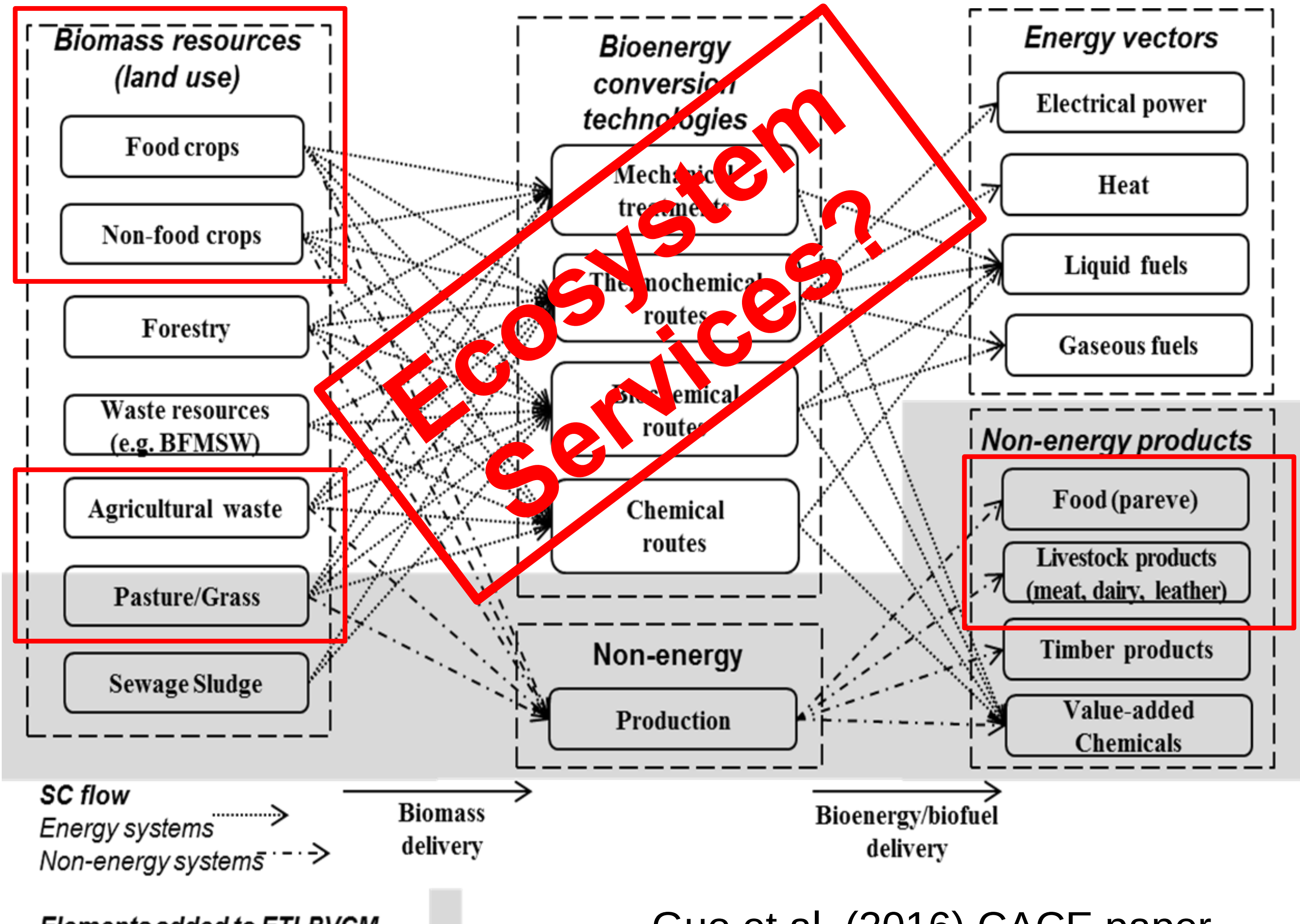
Land sharing

Increases impacts (ALCA) due to less intensive agriculture

ALCA approaches (used in regulation) do not fit with ‘whole farm’ analyses

CLCA shares the responsibility of impacts between different players (making it difficult to regulate?)

Bringing non-energy systems into bioenergy optimisation model



Guo et al. (2016) CACE paper

Modelling diverse grassland types

ROTHAMSTED RESEARCH

Extensive and rough natural permanent grass crop systems

- Conservation area
- High carbon and biodiversity

Extensive but fertile natural permanent grass systems

- Often Sites Special Scientific Interest (SSSI)
- Very high biodiversity

Intensive and well-managed re-sown grass crop systems

- Purely agricultural land
- Low biodiversity / high emission

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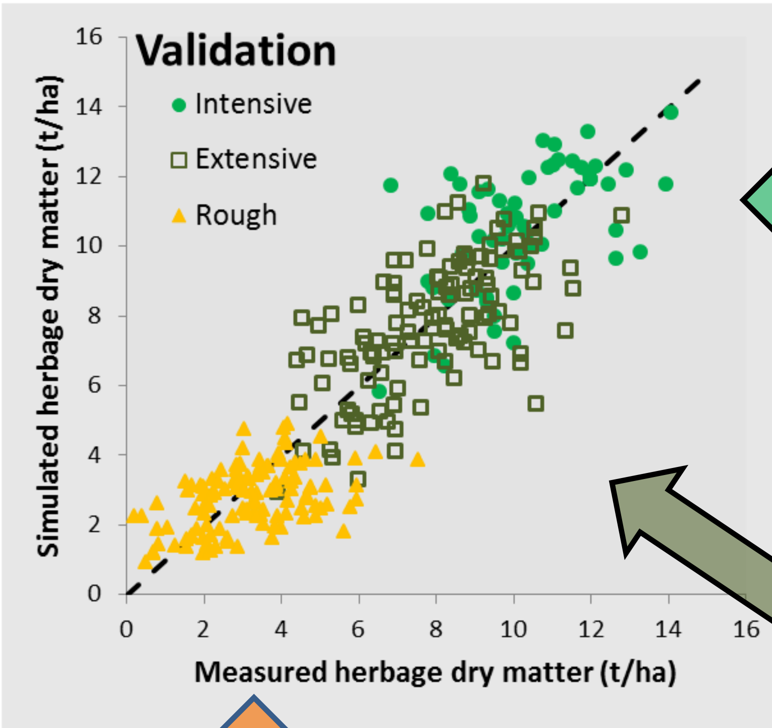
Modelling grassland types

ROTHAMSTED RESEARCH



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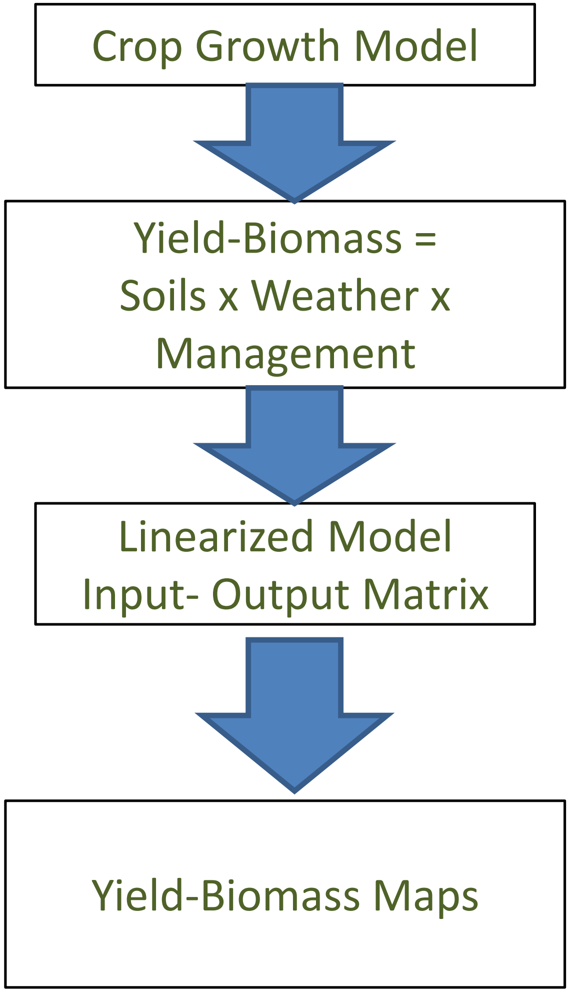
Up-scale Process- to Meta-model

ROTHAMSTED RESEARCH

- Calibrate process-model LINGRA-type sink-source
- Run representative scenarios
- Regress yield / biomass versus aggregated input variables
- Project feedstock distribution on 1 x 1 km grid



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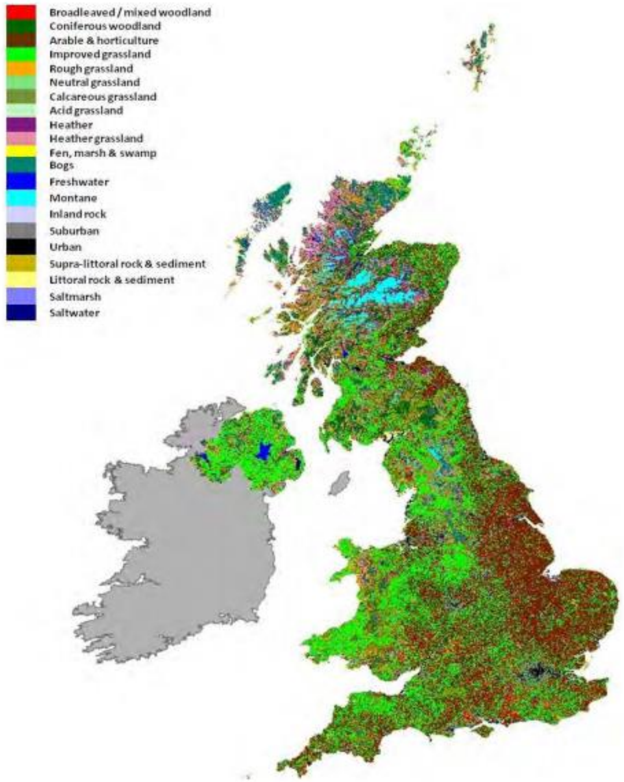
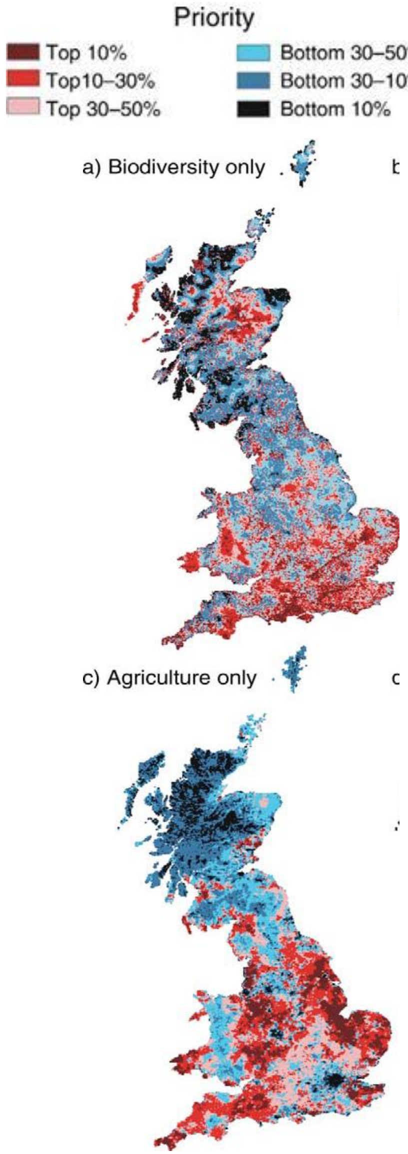


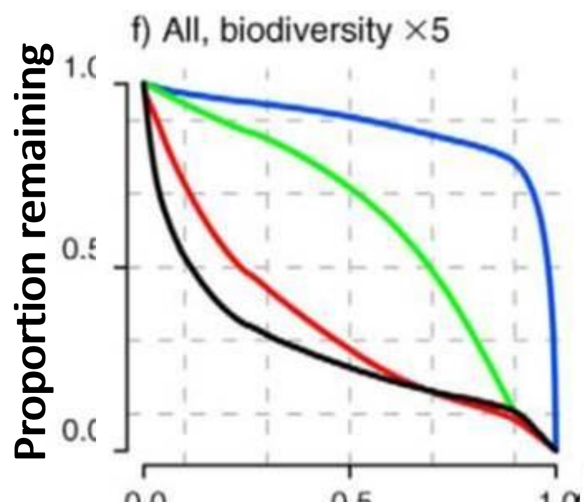
From qualitative to quantitative

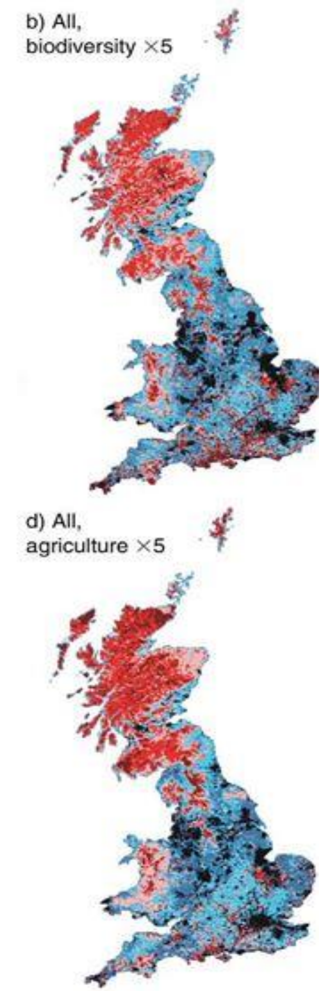
INTEGRATE ECOSYSTEM SERVICES (BIODIVERSITY)

Agriculture–Biodiversity antagonism



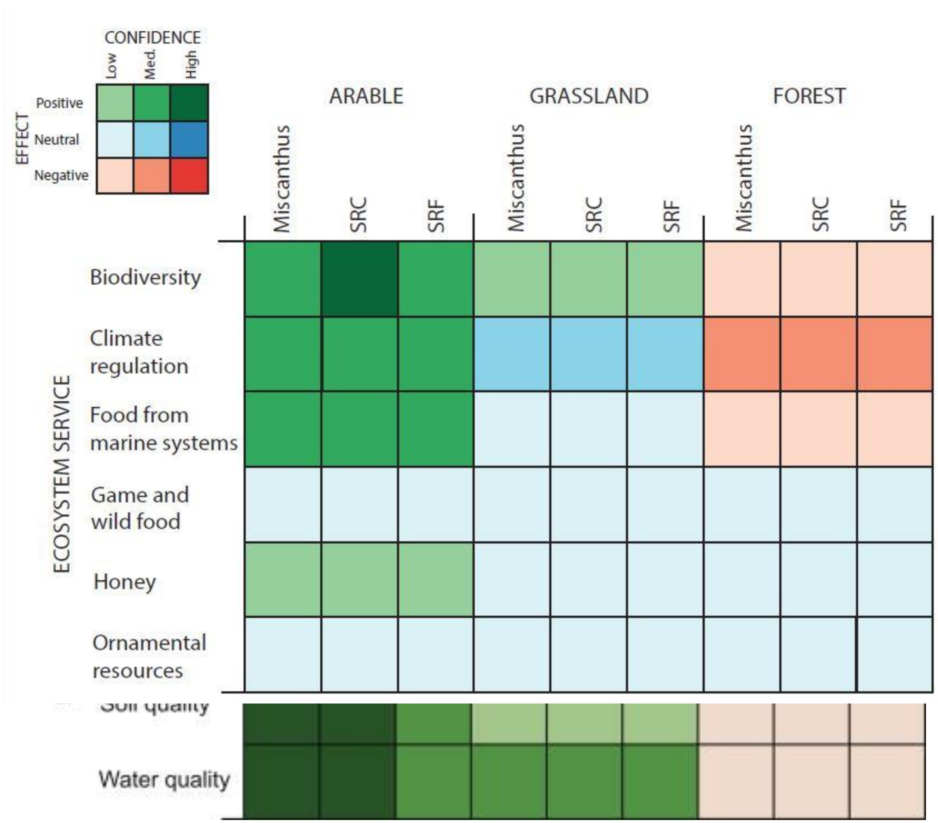
- Priority areas are in different locations
- Biodiversity collocates with agriculture
- 30% overlap suggests potential conflict
- There could also be synergies
- Performance curves weigh effects for area removal
- Weighting can be changed with trade-off in other land use criteria





Moilanen *et al*. (2011) Ecological Applications 21:1419-26

Representing biodiversity in LUC to BE



Qualitative 3-class ranking

- Total of 61 unique studies with 179 effects for 2G feedstock
- 121 transitions from arable
- 45 transitions from marginal land and 13 from forest
- Most studies on climate (66) and hazard (11) regulation
- Second most on soil quality (29) – 18 on water quality
- Few on biodiversity indicators: pollination (5) and pest - disease (7)

Holland *et al*. (2015) Renew. Sustainable Energy Rev .46;30-49
http://dx.doi.org/10.1016/j.rser.2015.02.003

ROTHAMSTED RESEARCH

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Integrating ESs into Value Chains

- Decide allocation hierarchy (Land Classification e.g. marginality)
- Determine *a priori* constraints (physical, cultural, etc)
- Generate yield scenario maps (1 x 1 km^2)
- Link to respective CO_2- & N_2O emission and sequestration
- Biodiversity maps at 10 x 10 km grid (e.g. 400 species in UK Biodiversity Action Plan)
- Apply ZONATION model (Moilanen) to maximize biodiversity or other ES subjected to yield and other feedstock criteria
- Grid wise allocation according to optimization criteria
- Down-scale to decision making at farm and landscape level

Key background questions - purpose

Underlying drivers

- What is our ultimate socio-economic aim? – What is the "beyond" of "more food for more people"…

Methodology

- Do we have the tools to measure and model bio-diversity effects? – Data and technology quest….

Governance

- Who should watch over implementation and ensure compliance?

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