Measuring sustainable intensification: Combining composite indicators and farm efficiency analysis

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Outline

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- Environmental Indicators
  - Agri-environmental payments
  - Grassland+permanent area
  - Land use diversity measured by the Shannon Index
- Efficiency (SI) analysis of cereal farms in England and Wales
  - Composite indicators
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- Some thoughts

The idea

- Externalities associated with agricultural production have been a driver in the design of agricultural policies in the EU in the last decades
- 'Sustainable intensification' (SI)
  - simply improved resource use efficiency, i.e. 'producing more with less'
  - A more complete understanding of SI has to encompass the positive and negative externalities of agriculture
- Generating models of sustainable agriculture is not easy
  - Heterogeneity of environments and production systems
  - Heterogeneity of societal awareness, understanding of interlinkages and value of ecosystem services
- Different definitions for SI (e.g. FAO, 2011; Royal Society, 2009; Pretty, 1997)

The idea

- Different interpretations of SI lead to different approaches to measure SI
- Questions all approaches face are:
  - What dimensions of SI need to be measured?
  - What metrics are appropriate to capture these dimensions?
  - How can these metrics be combined into a composite measure of SI, i.e. under what weighting system?

The idea

- Buckwell et al. (2014) suggested that provisioning and environmental dimensions can be seen as two dimensions of a production possibilities frontier (PPF), where the PPF serves to 'depict the challenge of sustainable intensification'.

- We needed an approach that allowed to account multiple outputs and inputs as well as environmental externalities associated with agricultural production

- We estimate the farm level efficiency concept through the use of an output distance function (Coelli et al., 2005).
  - Data Envelopment Analysis (mathematical programming)
  - Stochastic Frontier Analysis (econometric estimation)

The idea

- The obtained efficiency estimates, once economic and environmental aspects are incorporated, can be used as a Farm Sustainability measure

- Incorporating environmental aspects as in Areal et al. (2012)
  - Environmental impacts associated with cereals production
    - positive externalities

The idea

- 4 models
  - M1: No environmental output is taken into account
  - M2: Environmental output is taken into account using Agri-environmental payments as an indicator for environmental externalities
  - M3: Environmental output is taken into account using grassland and permanent area as an indicator for environmental externalities
  - M4: Environmental output is taken into account using Land use diversity measured by the Shannon Index as an indicator for environmental externalities
- We incorporate composite indicators for the provision of environmental goods as another dimension to the standard technical efficiency analysis.
  - Up to now the use of composite indicators can only reflect fixed and usually pre-determined levels of expression of the provisioning and environmental dimensions making them of limited value to policy makers
  - SI can be achieved through different means

Dataset

- Farm business survey (FBS)
  - 106 cereal farms in England and Wales during the period 2010-2012 (balanced panel data)
  - Farm output data
    - cereals enterprise output (£)
    - other enterprise outputs –other crops and livestock- (£)
    - environmental output (measured by a set of indicators)
      - Agri-environmental payments (£)
      - Grassland and permanent area (EI = $\frac{Permanent\ grasland+permanent\ grassland}{UAA}$)
      - Land use diversity measured by the Shannon Index
  - Farm inputs data
    - utilised agricultural area (ha)
    - labour (number of hours)
    - machinery costs (£)
    - other costs, including crop protection and animal costs (£)
  - Information of the geographical location of the farm at the 10x10 km grid level

Dataset

Explanatory dummy variables for inefficiency

- Farmer's age [average=57; if age≥ $57 = farmer's\ age = 1$; otherwise=0]
- Farmer's education [degree or postgrad=1; otherwise=0]
- Financial pressure (ratio between total external liabilities and total assets) [=1 if ≥ 0.20; =0 otherwise]
- Assurance scheme [yes=1;no=0]

The environmental indicators

- Agri-environmental payments received
  - Environmentally Sensitive Areas
  - Organic Aid Scheme / Organic Farming Scheme
  - Countryside Stewardship Scheme
  - Woodland Grant Scheme
  - Farm Woodland Premium Scheme
  - Tir Gofal (Wales only)
  - Entry Level Stewardship
  - Organic Entry Level Stewardship
  - Higher Level Stewardship
  - Tir Eryri (Wales only)
  - Upland Entry Level Stewardship
  - Organic Upland Entry Level Stewardship

The environmental indicators

- Grassland indicator

$$EG = \frac{permanent\ grassland + rough\ grassland}{total\ agricultural\ area}$$

Permanent and rough grassland are reported to be likely to contribute to positive environmental effects (Altieri, 1999; Gardner and Brown, 1998; OECD, 1999)

- Many bird species are dependent on permanent pasture
- Prevention of soil erosion
- Renewing ground water
- Flooding control
- Development of microorganisms in the soil
  - Decomposition of plant residues, manures and organic wastes

EC Regulation 1782/2003 permanent pasture has + environmental effects and as a consequence it is appropriate to adopt measures to encourage maintenance of existing permanent pasture to avoid massive conversion to arable land

The environmental indicators

- We adopt a widely-used diversity indicator, the Shannon Index, to create an indicator of land use diversity (LUD).

$$LUD = -\sum_{c=1}^{C} a_c \times \ln(a_c), LUD \geq 0$$

where a_c is the area occupied by crop c and C is the total number of crops.

- A high index value indicates higher crop diversity.
- It is a metric of the number of land use classes on the farm and their proportional representation.
- There is growing evidence that biodiversity is positively affected by heterogeneity in agricultural crop types (Siriwardena et al. 2000; Benton et al. 2003).
- Measures to promote crop diversity have been incorporated into the greening measures of the 2015 CAP, to increase the supply of these environmental goods.

Composite indicators

- Weights given to each indicator are crucial in their interpretation
- There is often no way to judge the relative importance of different environmental indicators
  - appropriate weights have never been systematically generated
  - consensus on the relative importance of environment dimensions cannot be reached
- A single farm SI score, based on a fixed combination of outputs
  - too limiting
  - subject to user bias
  - ignores equally valid alternatives
  - provides no information on its uncertainty
- We use every possible weighting combination accounting for the range of possibilities that farmers have available to provide environmental outputs (Areal and Riesgo, 2015)
  - We assume that SI can be achieved by a distribution across different combinations of outputs

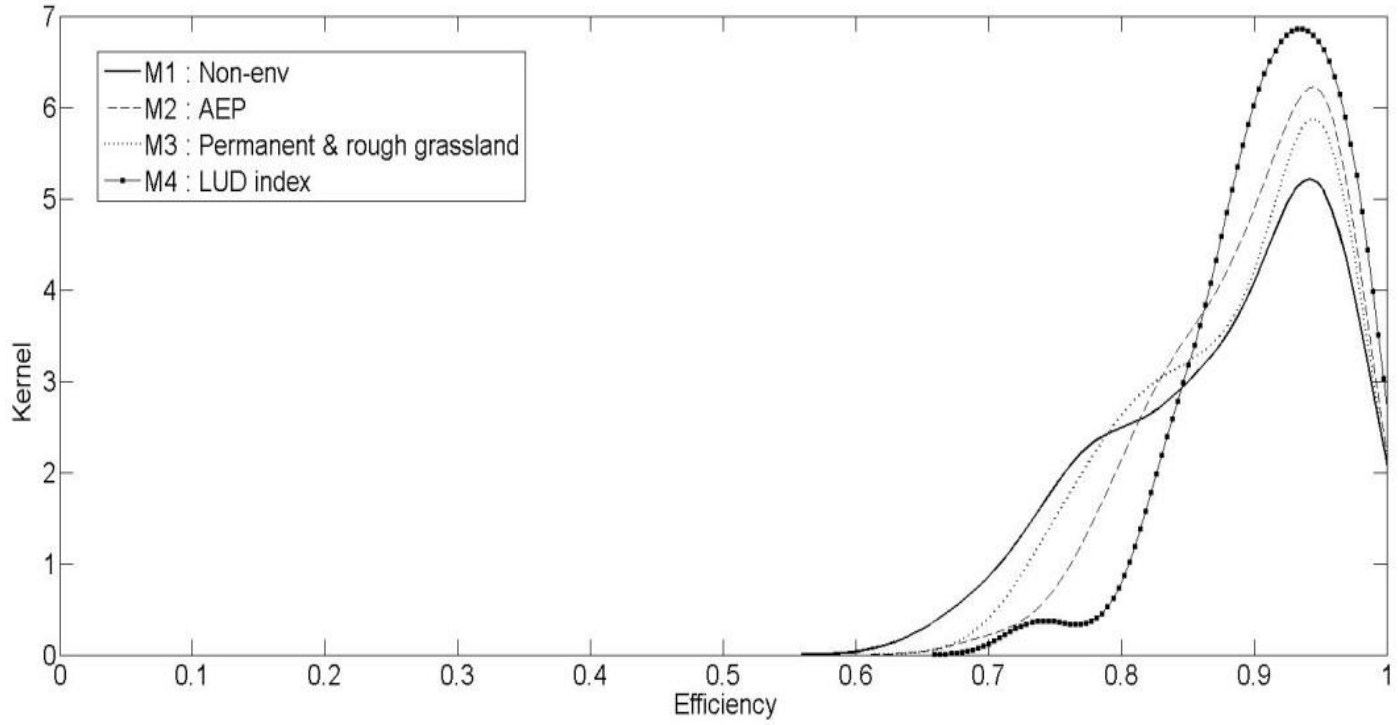
Composite indicators

- We build a 106×3 matrix EG using the 3 indicators for the provision of environmental goods
- Each indicator is normalised using the distance method $\left(EG_i = \frac{eg_i}{max(eg)}\right)$, which measures the relative position of an indicator to a reference point, in this case the maximum value of the indicator in the sample. This allows us to rescale each indicator to a dimensionless scale $(0, 1]$.
- In order to build a composite indicator of provision of environmental goods (CEG) we need to weight and aggregate the individual indicator matrix EG as follows:

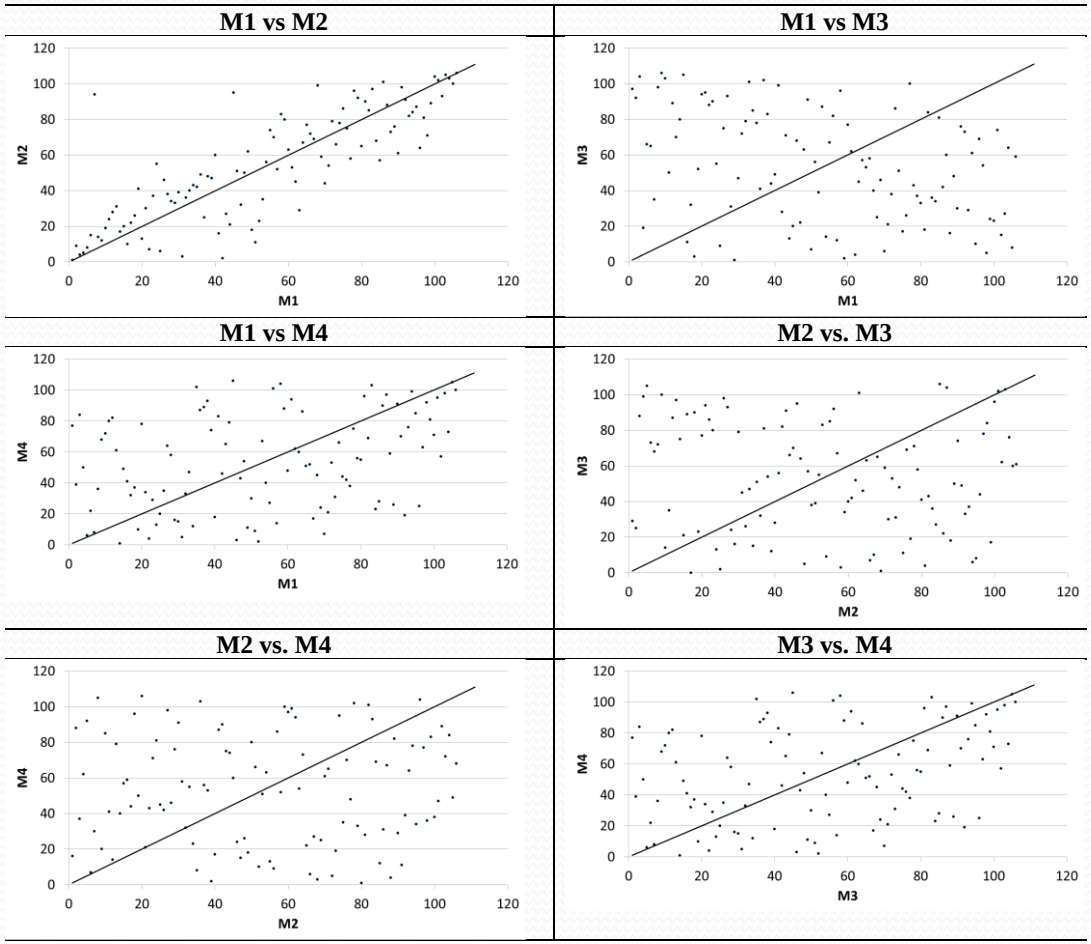
$$CEG = EG \times W'$$

- The steps followed are:
  - Each element of W can take values {0,0.1,0.2,…,1},
  - The sum of elements in each row equals 1.
  - The total number of combinations holding these rules is 66, meaning that W is a 66×3 weighting matrix.
  - We obtain CEG, a 106×66 matrix (i.e. 66 composite indicators for the provision of environmental goods to create a composite indicator of SI (CSI)).
  - We run 66 models using each of the weighting combinations to obtain 66 CSI per farm.
  - Farms are then ranked, relative to other farms, according to how well they score in each of the 66 CSI.
  - This information is summarised in a farm rank distribution representing individual farm SI performance.
  - As an illustration of the possibilities of using this information for policy purposes, farms are grouped into four distinct classes according to their performance on all 66 indicators.

Kernel distributions of the posterior means of technical efficiency (SI) across all farms for M1, M2, M3 and M4.

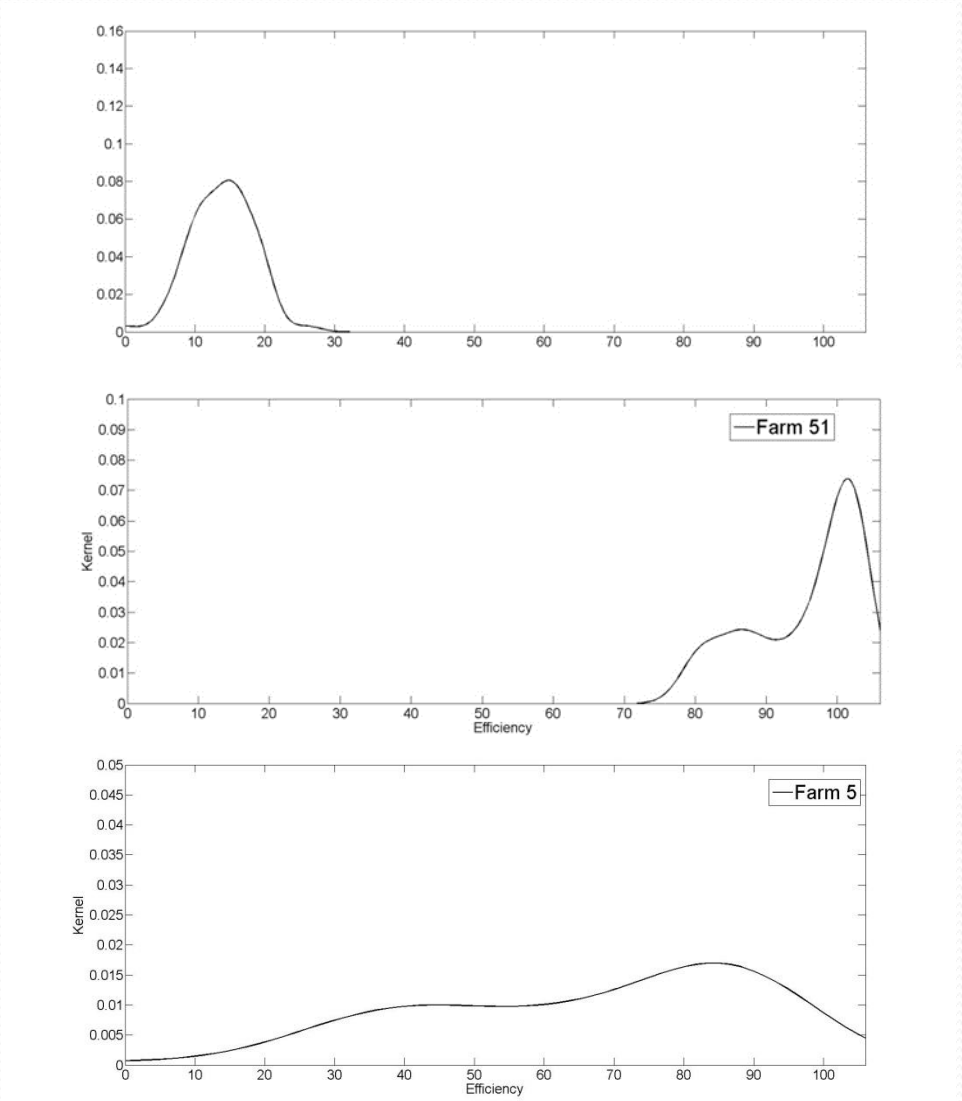


Scatter plots of rankings of efficiency scores



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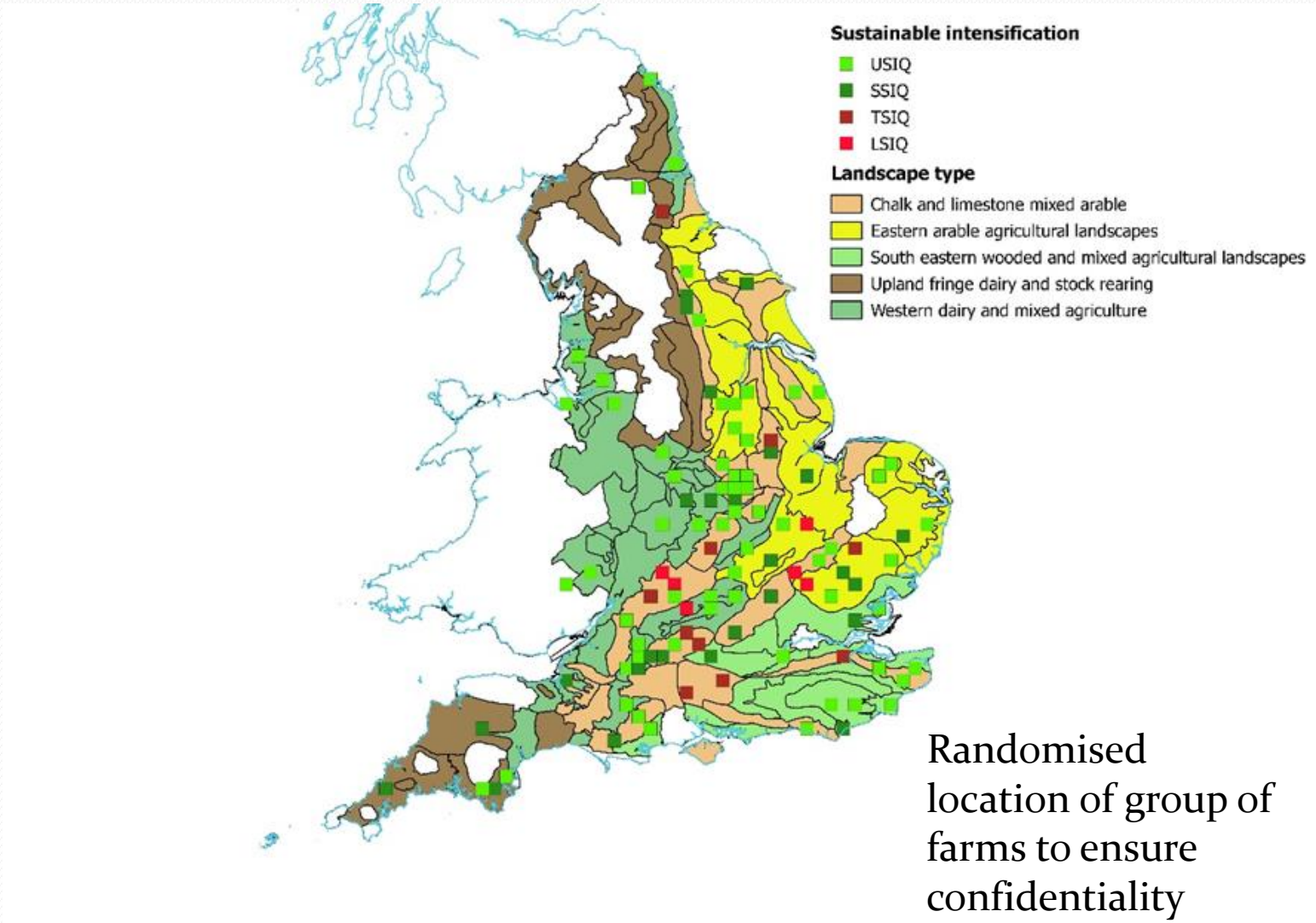
Kernel distributions of individual farm ranking based on SI scores



Discussion

- How robustly farms can be classified according to their SI performance?
- How can policy makers decide on the level of support, incentive, or regulation, farms may require to enhance their SI performance?
- Classify farms into:
  - a) the upper SI quartile (USIQ), i.e. farms that are within the first quartile of the distribution under at least one SI indicator
  - b) the second SI quartile (SSIQ), i.e. farms that are not in the first quartile but fall into the second quartile under at least one indicator
  - c) the third SI quartile (TSIQ), i.e. those that are not in the first two quartiles but are in the third quartile under at least one indicator
  - d) the lower SI quartile (LSIQ), i.e. farms that always fall into the fourth quartile irrespective of the environmental indicator used

Spatial distribution of SI performance by groups (upper SI quartile, second SI quartile, third SI quartile, lower SI quartile) and landscape type



Randomised location of group of farms to ensure confidentiality

Conclusions

- The choice of SI metric has clear impacts on the relative farm SI performance
- Most farms are seen to be engaging in at least one practice that can be classified as 'contributing to sustainability'
- Incentives required to promote SI and environmental outputs need to be context-specific (Armsworth et al., 2012) and feasible within the landscape or catchment where the farm exists

- How can policy makers draw upon these metrics of SI in order to implement evidence-based policies for the benefit of society and sustainability?
  - Policies based on a narrowly define SI, i.e. a 'one-size-fits-all' model, are inherently flawed and likely to lead irrational policy goals and impacts in some areas due to the heterogeneous nature of landscapes
  - the SI metric proposed here, or rather the general approach taken in its construction, provides a positive contribution towards this goal by capturing more of this context-complexity than it peers

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Measuring sustainable intensification: Combining composite indicators and efficiency analysis to account for positive externalities in cereal production

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ABSTRACT

We combine the use of a stochastic frontier analysis framework and composite indicators for farm provision of environmental goods to obtain a farm level composite indicator reflecting sustainable intensification. The novel sustainable intensification composite indicator that is developed accounts for multidimensional market and non-market outputs, namely the economic performance of cereal farms (i.e. market production value) and the associated positive environmental impacts of production (e.g. positive environmental externalities). The composite indicator integrates three different indicators for the provision of environmental goods into a stochastic frontier analysis: a) agri-environmental payments; b) the ratio of rough grassland and permanent pasture area to total utilised agricultural area; and c) land use diversity, as measured by the Shannon Index. We apply this approach to a panel of data for 106 cereal farms in England and Wales during the period 2010–2012. Results indicate that farm rankings on the indicator vary substantially depending on the weight given to the different environmental aspects/indicators, suggesting that single indicators of the provision of environmental goods may not provide a true reflection of the environmental performance of farms. We illustrate a simple approach that captures the aspects of sustainable intensification of farms in a much more holistic way, i.e. by producing a distribution of sustainable intensification scores for each farm reflecting different weightings of evaluation criteria. To reduce the dimensionality of this distribution farms are classified into four distinct groups according to the shape of this distribution, with some farms found to perform well under all combinations of weights for evaluation criteria, while others always perform poorly. This distribution-based analysis provides a greater depth of information than traditional approaches based on the generation of a single sustainable intensification score.

1. Introduction

promoting ecosystem services beneficial to production (Plieninger

Thank you!