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# Evidence of sustainable intensification among British farms

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ABSTRACT

Several influential reports have suggested that one of the most appropriate responses to expected food shortages and ongoing environmental degradation is sustainable intensification, i.e. the increase of food production with at worst no increase in environmental harm, and ideally environmental benefit. Here we sought evidence of sustainable intensification among British farmers by selecting innovative arable, dairy, mixed and upland farms and analysing their own data on yields, inputs and land use and management for 2006 and 2011. The evidence was obtained by interview, and was interpreted in terms of the ecosystem services of food production (GJ $ha^{-1}$, where area took into account estimated area to grow any imported animal feeds), regulation of climate, air and water quality (modelled emissions of GHGs ($CO_2e\,ha^{-1}$), ammonia (kg $ha^{-1}$) and nitrate loss (kg $ha^{-1}$)) and biodiversity (using an index based on the presence of habitats and management).

Several farms have increased both food production and other ecosystem services over this time by increasing yields, using resources more efficiently and/or enhancing biodiversity, and sometimes by reducing livestock numbers and increasing cropping. The motivation has been to improve farm profitability through increasing food production, reducing input costs and accessing public payments through agri-environment schemes and generating renewable energy. Such sustainable intensification was not achieved by farmers who increased meat or milk yields.

Sustainable intensification can be achieved when the correct drivers are in place to influence the actions of individual farmers. Also, it is possible to indicate sustainable intensification by using a small number of high-level indicators derived from data that farmers already hold, though such an approach may not capture the impacts of farmer innovative practices.



## 1. Introduction

During the second half of the 20th century, global agricultural production increased at rates that were sufficient to keep pace with demands. Concerns about global food security focused on issues of equity and distribution, rather than worries about the total amount of food available around the world (McIntyre et al., 2009). The global spike in food prices in 2007–2008 changed perceptions markedly, and brought attention to the fact that global demand for food was starting to rise faster than supply. The concept of 'sustainable intensification', in which "yields are increased without adverse environmental impact and without the cultivation of more land", was developed to highlight the need to improve agricultural productivity without incurring the kind of environmental costs associated with intensive agriculture in the past (Royal Society, 2009; see also Foresight, 2011). Some authors consider that sustainable intensification should go further than requiring no additional environmental harm, but should involve increases in both food production and the flow of ecosystem services (e.g. Firbank, 2009; Pretty et al., 2011).

While there are many cases in Africa where increases in yield have been associated with improved environmental outcomes, such as by improved management of highly degraded soils (Pretty et al., 2011), there is very little evidence of sustainable intensification among commercial farms of temperate regions. This is partly because most published studies of changing levels of production and environmental impacts have looked at interactions between two variables at the national level, rather than at the individual farm (Firbank et al., 2011), and partly because sustainable intensification is easier to observe from low baseline yields and environmental performance. Also, in temperate regions, sustainable intensification is widely perceived more as a strategy for the future than a desirable change in the present (Foresight, 2011). Yet the pressures on agricultural production in temperate regions are already increasing; at the time of writing, there is likely to be a drawdown of global cereal stocks because of the poor weather, including the prolonged and severe drought in the US (FAO, 2012), which itself is consistent with a shift towards less

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**Table 1**
Percentage composition of generic compound formulations for animal feeds. These values were used to estimate the amount of crops required to make up the diets of animal feeds imported to the farm, which were then used to estimate the land required to grow the animal feeds, using average UK yield data. Minor feed constituents are not included.

| | Dairy | Beef | Sheep | Fattening pigs | Poultry |
|---|---|---|---|---|---|
| Wheat | 15 | | 10 | 45 | 45 |
| Barley | 20 | 40 | 22 | 20 | 20 |
| Wheat and other cereals | 20 | 21 | 15 | 9 | 9 |
| Oilseed rape meal | 20 | 20 | 10 | 11 | 11 |
| Soybean cake and meal | 5 | | 5 | 7 | 7 |
| Sunflower cake and meal | | | 5 | | |
| Field beans | 5 | | 10 | | |
| Sugar beet feed, dried molasses | 8 | 12 | 15 | 3 | 3 |

favourable weather conditions for temperate agriculture (Francis and Vavrus, 2012). It is therefore important to ask whether sustainable intensification is already being delivered by some farmers, what strategies they are adopting and why, what barriers they are facing and what are the inherent risks. Only once these questions are answered will it be possible to design interventions that will encourage sustainable intensification in appropriate situations.

Innovation in sustainable intensification is most likely to be found among the more progressive farms. Therefore, our approach was to identify a group of such farms, to test whether sustainable intensification has been achieved. We collected data on agricultural production and measures of environmental impact, and discussed with farmers their drivers, motives and perceived barriers to implementation of sustainable intensification. We relied entirely upon data already available to the farmer, so that the methodology can readily be applied to much larger samples of farms at low cost in due course, for example to support certification of environmental standards at the farm scale.

## 2. Methods

### 2.1. Quantifying sustainable intensification

Sustainable intensification is a process, rather than a condition at any time. In the absence of an agreed set of metrics of sustainable intensification, we adopted a very pragmatic approach. A farm was considered to be practicing sustainable intensification if food production per unit area had increased during the study period, and that none of the environmental variables had deteriorated. Changes were analysed in both agricultural production and a representative set of environmental variables from a baseline of 2005–2006, i.e. before the global increases in food prices, to 2010–2011, the most recent data for which most farms have data (in some cases, we had to use data from different years). We adopted a small number of variables, to allow a qualitative assessment of sustainable intensification (following Pretty et al., 2008a,b), which we regarded as being more transparent than interpreting sustainability by integrating a larger number of variables into a common unit, for example money (Bateman et al., 2011). The system boundary was the farm gate.

The measurables were taken from five major categories of ecosystem services that are known to have changed significantly across the UK on farmland (UKNEA, 2011), namely agricultural production, biodiversity, climate regulation, regulation of air quality and regulation of water quality. For ease of interpretation, we used a single variable to represent each of these categories for each individual farms, measured on the basis of land area, and per unit food production. We used only data already held by the farmers, interpreted using commentaries obtained during farm visits and interviews; this restriction excluded some ecosystem services and processes that could not therefore be reported with acceptable precision, notably landscape quality and levels of soil erosion from the farm.

Data were collected on food production by the whole farm area. This comprised the total land area of the farm (including non-productive areas), supplemented with estimates of the area of land required to produce feeds brought onto the farm. These estimates were obtained using data on generic compound formulation (Table 1) to break down compound feeds into estimated amounts of constituent crops (wheat, barley, oilseed rape), and then UK average yields of these crops were used to estimate areas of land used to grow them. We did not attempt to distinguish between different sources of such imports.

In order to generate a single measure of food production, we condensed the available data into gross energy per unit area, i.e. GJ $ha^{-1}$, where energy content of foodstuff were taken from multiple sources (Table 2) and the area was for the whole farm as calculated above. This metric allows changes to be tracked for an individual farm, but is not suitable for comparison across farms as it ignores variation in the financial and nutritional value of different foodstuffs and is closely related to the potential of the farmland for food production in terms of soil and climate. In order to avoid double counting, the energy content of cereals and fodder crops used for the farmers' own livestock were not included in the analyses.

Carbon footprints were estimated for the farms by combining two approaches. Carbon dioxide emissions ($CO_2$) were calculated using the CALM tool (CLA, 2012), that allows for energy use and land use change using values taken from UK Greenhouse Gas Emissions Inventory (DECC, 2012). Potential emissions of methane and nitrous oxide were calculated using the Farmscoper tool (Gooday and Anthony, 2010), that uses data on cropping, soil type and rainfall, livestock numbers, fertiliser use and housing to estimate gross emissions for each gas in kg $ha^{-1}$. Methane and nitrous oxide emissions were then converted into Global Warming Potential (in $CO_2e$) and combined with the $CO_2$ emissions to give a total carbon footprint. These estimates do not allow for variation in farm practices,

**Table 2**
Energy content of agricultural produce, used to estimate energy content of food produced from the farms. FW = fresh weight; DM = dry matter. Data are compiled from Chan et al. (1995); and the UK Nutrient Databank Food Standards Agency (FSA) (undated). All meat weights relate to raw, trimmed lean portions, supplemented by estimates of the energy content of the non-consumable proportions of livestock (Kempster et al., 1985; BPEX, 2012).

| | Energy content |
|---|---|
| Beef | 5.7 GJ/t FW |
| Lamb | 6.5 GJ/t FW |
| Pork | 5.2 GJ/t FW |
| Poultry | 5.2 GJ/t FW |
| Milk | 2.8 GJ/1000 l |
| Wheat | 18.4 GJ/t DM |
| Field beans | 18.6 GJ/t DM |
| Sugar beet | 14.0 GJ/t DM |
| Potatoes | 13.0 GJ/t DM |
| Vegetables | 6.0 GJ/t DM |
| Soft fruit | 7.1 GJ/t DM |