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# Measuring progress towards sustainable intensification: How far can secondary data go?

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ABSTRACT

A number of influential policy documents have championed sustainable intensification as an approach to meet the challenge of a growing population under increasing land constraints. Whilst there has been some discussion on how to define sustainable intensification, few studies have provided frameworks for measuring progress.

This paper develops an approach using data from the Farm Account Data Network for a balanced panel of 42 beef farms within Scotland. Indicators reflecting economic, environmental and social parameters are derived from this database and measured over the period 2000–2010. These variables are objectively weighted to construct an overall index using positive matrix factorisation (PMF), a form of factor analysis, which is appropriate when handling environmental quantities. We find little change in Scottish beef farming with respect to sustainable intensification, which reflects both a policy which has not supported intensification or output expansion over this period, nor has it increased economic, social or ecosystem sustainability over this period.

We argue that secondary data is a valuable resource for creating indicators for all these areas of policy interest and data from the farm account networks emphasises the production elements of farming, which is central to definitions of sustainable intensification. However, within the score itself there is a great deal of variance which highlights caution in how to use a single indicator to fully reflect progress towards this goal.



## 1. Introduction

Emerging global research and policy agendas are now based on the sustainable management of agricultural land. This aligns with the requirements of a number of countries and international bodies which are searching for land management solutions aimed at balancing socio-economic and ecosystem service management provision (Pretty et al., 2011; Foley et al., 2011).

Most of the concern has centred on the limited land for agricultural activity which must maintain and enhance productivity and yields to meet the forecasted demand from a growing population (Royal Society, 2009; Geraldo et al., 2012). The result of this has been support for the sustainable intensification of agricultural production within agriculturally dominant landscapes (Ambler-Edwards et al., 2009; FAO, 2010; Jaggard et al., 2010). A common definition of sustainable intensification (Pretty, 2008; Royal Society, 2009; Godfrey et al., 2010; Conway and Waage, 2010; Pretty et al., 2011) is:

> *Sustainable agricultural intensification is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services*

Intensification has been the main cause of loss in the range of ecosystem services provided by agriculture (Firbank et al., 2011; Storkey et al., 2011) and this definition clearly aims to address these specific impacts. A number of studies have argued for wider definitions to encompass economic and social dimensions of sustainable intensification (Barnes et al., 2011a; Garnett et al., 2013). These have argued for an ethical dimension with respect to both the treatment and ownership of land, but also the management and welfare of animals (FAO, 2004; Barnes et al., 2011a).

Furthermore, in developed, high income economies agricultural productivity growth rates have either slowed or have reached a plateau (Fuglie, 2010). Some commentators have suggested that this is a result of over-exploitation of the natural resource base for production (Pimentel et al., 1995; Doran and Safley, 1997; Matson et al., 1997; Cassman, 1999). Overall, the history of over-exploitation of resources that has occurred, in addition to issues

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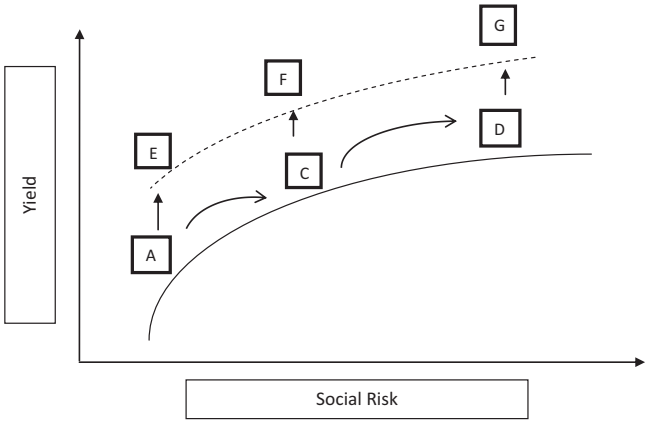


**Fig. 1.** Risk-return framework applied to sustainable intensification.

related to over-consumption and waste (Foley et al., 2011) presents a complex paradigm for assessing progress towards sustainable intensification within these countries.

### 1.1. Conceptual background

Keating et al. (2010) proposed a return-risk framework as means of understanding eco-efficiency, based primarily on the production function concept, and this is also useful for understanding the impact of sustainable intensification. Risk-return can be rather generic in terms of the return and the risk explored. Fig. 1 represents yield growth measured against social risk (which is used here to reflect various dimensions of environmental, economic and wider social and ethical aspects of society). The various points (indicated by letters) represent stages in the trajectory of the farm towards intensification.

The thick line indicates the technology frontier. That is, given this particular system, the farm is operating at the most efficient it can be, with the level of technology available in that industry. Technology is therefore the major constraint to improving yield. The only option for improving yield is to intensify production, that is move from point A to point C. Clearly, this increases the social risk, for example more resources are needed to produce more yield which, even on the efficiency frontier leads to an increase in the potential for damage. Moving from A to C does not therefore '*maintain or enhance natural capital*' (Pretty, 1995) and is clearly not sustainable intensification. Even more significant is the movement up the frontier to point D, whereby the change in yield is significantly less than the increase in social risk associated with intensifying. The only option is to see sustainable intensification as a new technology. This is represented by the dotted line where a farm can increase yield by shifting up to point E. Here yield has increased with no increase in social risk. However, moving along the new frontier (from E to F) is not possible as intensifying to increase yield increases social risk. Consequently, to meet the principal of sustainable intensification, this must be considered a new technology which reconfigures the relationship between inputs and outputs and effectively raises the frontier continously upward.

A number of measures are available for analysing environmental, social and economic change (Alberti and Parker, 1991; Welsch, 2005; Zhou et al., 2006; Munda and Saisana, 2011; Singh et al., 2012). These are all based on the presumption that no single indicator could offer enough information for policy-makers. However, Esty et al. (2005) argued that a composite environmental index gives condensed information for policy evaluation, benchmarking and, ultimately, decision-making. Most studies generating a composite indicator have focused on country level estimates of progress (Böhringer and Jochem, 2006), whereas only a few focus specifically on the agricultural sector (Barnes, 2002; Ball et al., 2004; Barnes et al., 2011b; Areal et al., 2012). Nevertheless, no work has been directed at the specific issues of measuring sustainable intensification within an indicator framework. However a significant amount of secondary data exists on agricultural and related environmental production over a large time period. This is mostly as a consequence of subsidy payments, which require farmers to report on-farm and off-farm activity. One such data set is provided by the EU Farm Account Data Network (FADN) which has been collected from the early 1980s onwards and gives individual farm level data on outputs, inputs and other land uses for each country within the European Union. Consequently, whereas primary data might be ideal for understanding sustainable intensification, these will usually not present adequate detail over time to assess progress. From a policy making context secondary data such as the FADN provide a cost-effective means to explore measurement metrics, but also identify possible opportunities for development of these databases.

The composite indicator approach has been explored and championed by a number of researchers (Alfsen and Saebo, 1993; Yu et al., 1998; Zhou et al., 2006; Zhang and Yang, 2007). The key decision when searching for an overall indicator is the approach to deriving and applying weights. In relation to sustainable intensification the various dimensions need weighting criteria, as do the underlying variables which characterise these dimensions. With respect to sustainable intensification this is a dynamic process. For example, food production related issues have had an interesting and fluctuating influence on policy makers throughout the last twenty years. Food production was the central concern of farming in the 1980s, as high income countries were promoting output expansionist policies through their respective subsidy systems. However society over the last 20 years has become increasingly critical of the loss of environmental quality at the public expense of generating output surplus from these policies. Recently the influence of national and international policy documents tend to suggest that food production is becoming a rising concern again and should have a higher weight within an overall index of sustainable intensification when compared to 10 years ago (World Bank, 2008; IAASTD, 2009; FAO, 2009; Defra, 2010; DAFF, 2010). Ripoll-Bosch et al. (2012) used workshops to generate weightings on a farm by farm basis with respect to intensification. However, focusing on specific policy, public and farmer dimensions could lead to bias and conflicting weights attached to various factors within intensification strategies. Eliciting fair weights and analysing the trade-offs between stakeholders involved within sustainable food production and consumption is a key area for future research (Diaz-Balteiro and Romero, 2004; Esty et al., 2005; Gómez-Limón and Sanchez-Fernandez, 2010). Accordingly, the approach used here applies a statistical weighting technique, known as positive matrix factorisation (PMF), as a means to provide a baseline index for eliciting objective weightings.

The aim of this paper is to provide a methodology for assessing sustainable intensification over time. This is outlined using a regional case study of beef farmers in Scotland and an index is constructed from secondary data. The next section discusses the data and how the indicators were developed. This is followed by the statistical approach used for weighting separate indexes. Results are then presented and this is followed by discussion of key points and issues in implementing an overall index. Finally conclusions are drawn for future research and policy.

## 2. Materials and methods

### 2.1. Data

We focus on the Scottish beef sector which provides a national level enterprise that has been identified as a sector with significant