Sustainable Intensification in Scotland

A Discussion Document

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Executive Summary

Sustainable intensification has been promoted by a number of influential national and international policy groups as the solution to meeting the nutritional needs of a growing global population from a fixed or declining resource base. Sustainable agricultural intensification can be defined as (Pretty, 2010):

‘... 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’ (Royal Society, 2009; Godfray et al., 2010).

This report represents a discussion document for SAC’s Rural Policy Centre aimed at understanding some of the issues related to sustainable intensification and how this can be measured within the Scottish context. We also apply an approach using secondary Farm Account Data as a basis for discussion.

Intensification implies a change within the system over time and to be classed as sustainable it must both protect and enhance ecosystems services, but should also include economic and social factors, as well as ethical dimensions. This is illustrated in the Figure E1.

**Figure E1. Proposed four dimensions of Sustainable Intensification in Scotland**

![Diagram of four dimensions of Sustainable Intensification](image)

The weighting of these four dimensions will vary across individuals involved in the production, supply and consumption of food products, as well as over time, as societal demands change. The time dimension also complicates development as technology will emerge which releases greater yield potential. Societal changes may lead to the acceptability or rejection of technologies which enable intensive food production, e.g. genetic modification, nanotechnology.

At the outset it is noted that Scottish policy documents are primarily focused on increasing the value of production, as opposed to physical output. Therefore, the intensification of
production must be managed in a way which does not affect the value of the Scottish brand, which is perceived as high quality production by the consumer. Within the wider EU policy framework, there is increasing emphasis on resource use efficiency. Consequently, this may affect whether we view sustainable intensification as an output enhancing technology or one that is based on resource saving.

To illustrate some of the issues with measuring sustainable intensification over time the Farm Account Survey (FAS) was used to derive indicators of intensification and of sustainability. A simple indicator from the FAS is stocking density (grazing livestock units per ha of grazing land) or, inputs per ha for cropping farms. We find no significant trend towards intensification over the 1989 to 2010 period of the FAS. Whilst this is stable, the FAS provides only farm level indicators. Variation would be expected at a field level, though these data are not available. In addition a range of sustainability indicators were generated from the FAS relating to ecosystem, biophysical, economic and social dimensions. Again the purpose was to illicit changes over time and some trends could be found. These indicators were then correlated with intensity and a series of positive and negative correlations were found. In particular, land productivity, reflective of biophysical capacity, seems to be strongly related to intensification variables for most farms. The ratio of rough grazing to total grazing area, reflective of ecological generation, is negatively related to intensification. The indicators of economic and social sustainability tended to vary by farm type but it was generally found that subsidies and debt burdens were positively related to intensity as was increasingly farmer hours relative to total hours worked on the farm, an indicator of farmer stress.

Principal components analysis (PCA) is a technique for determining the key variables in a multidimensional data set that explain the differences in the observations. This is a method of data reduction and provides a way of weighting of all variables related to the underlying structure of the data. However, weights for these different variables could also be derived from discussion with stakeholders, using participatory approaches for example. The PCA approach provides a relatively simple means of exploring issues of weighting different dimensions of sustainability and intensification.

Using this approach, a number of components were found for each farm type within the FAS. Notably, one component contained both intensification and sustainability variables. This is referred to as the Sustainable Intensification (SI) component. The mean scores for this component are illustrated as a web diagram below.
Figure E2. Mean PCA scores of the sustainable intensification component (SI) for the FAS farm types

For most farm types there are high scores for biophysical indicators, principally land productivity. In the case of cattle and sheep farms, there are also higher scores for the social dimensions, principally related to the mix of on and off farm labour. However, the other farm types tend to have lower scores for these social as well as economic dimensions of sustainable intensification.

This SI component, as described in the graph above, represents the actual performance of these farms with respect to sustainable intensification. Naturally, compared to figure E1 there are significant gaps which may need to be addressed with future policy towards development of sustainable intensification.

Examining this component over time, the frequency of membership (i.e. the number of farms within this component), has declined over time. An analysis of farm characteristics finds that size and tenure are key factors in membership of the SI component. Specifically, owner-occupiers are less likely to be in this group, as are farms which are bigger. However, for LFA farms this is reversed, namely the bigger farms are more likely to be in this group, probably due to the labour and grazing mixtures typified by these systems. Accordingly, we develop a number of discussion points:
**We need to agree on a definition of sustainable intensification for Scotland**

To be truly sustainable, we suggest, intensification of agricultural production within the Scottish context requires four dimensions to be met, namely:

i) it must maintain equity in incomes throughout the supply chain and across producers; specifically a fair return throughout the supply chain;

ii) it must strengthen the resilience of rural communities and maintain nutritional standards;

iii) it must maintain or enhance the stock of Scotland’s natural capital and the flow of ecosystem services emerging from this stock; and

iv) it must maintain or enhance the ethical dimension of agricultural production. This seems to be an underexplored area of sustainable intensification, which should include the treatment of animals under intensification systems, but also encompasses land ownership issues and access to land.

Defra have recently abandoned the term ‘sustainable intensification’\(^2\) to embrace the term ‘climate smart agriculture’. The FAO defines this as ‘an agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation) while enhancing the achievement of national food security and development goals.’

The requirement for ‘an agriculture which sustainably increases productivity’ would seem to encompass sustainable intensification strategies, and the four requirements above still hold to justify the sustainable dimension. However, the focus away from intensification shies away from the fact that we will have a limited amount of land to produce food on. Productivity is a loose term which allows for increasing levels of inputs into the production process, including land. As long as the rate of output is higher than the rate of input into the production system then productivity grows. Hence the focus needs to be on supply chain issues which address the quality and quantity of inputs into the production process. Finally, we argue that if any definition of sustainable intensification were adopted within Scotland, and for that matter any country, then some ethical debate is required over the treatment of people, land and animals to gain any higher output potential. Arguably, climate smart agriculture becomes a more nebulous term, and may mask some of the underlying debates surrounding how to sustainably feed a growing population.

**We need to develop measures of sustainable intensification**

Measuring sustainable intensification presents both conceptual and measurement difficulties. It is no inconsiderable task to ensure that progress is being made towards increased sustainability, whilst also reconfiguring a farming system towards more intensive production.

This firstly requires appropriate monitoring. Whilst the FAS provides indicators of input usage, it does not provide any spatial focus, nor activity at field or system level. Other data sets, such as IACS and census data could be merged with the FAS to provide a clearer picture on sustainable intensification. However, the intricacies of sustainable intensification could only be captured through detailed on-farm assessments over time which, naturally, has cost associations for policy makers. Secondly, strong multi-disciplinary working is needed to set measurement goals. If the four dimensions outlined above are adopted it infers that ecologists should work in conjunction with sociologists, economists and even ethicists, as well as perhaps wider disciplines, to ensure that these dimensions are fully

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\(^2\) No explanation could be found at time of writing but we presume this is due to the negative connotations related to the term intensification.
captured within the measurement process. Furthermore, it requires greater understanding of how to reconcile the (sometimes conflicting) indexes of sustainability and intensification which requires methodologies to extract weightings for individual indexes over different farming landscapes and, also, over time.

- **There seems to be no direct support for sustainable intensification within the policy literature.**

Scottish policy does not seem to support increases in output but focuses more on quality and adding value within the supply chain. Intensification seems to be a clear driver of output growth or for resource use efficiency. However, it is not the only driver. Farm production levels are the result of a complex nexus of present and future commodity prices, as well as production and non-production related subsidies; it also encompasses attitudinal and behavioural underpinnings, as well as the bio-geophysical constraints of farming. Nevertheless, the increasing supply of produce, from an output-expansionist approach, could, all things being equal, lead to lower food prices. Though, again, there are complex issues of maintaining equity within food commodity supply chains to achieve this.

- **A regional approach to policy making may be needed, with corresponding indicators of success**

This study finds differences in indicators of intensification and sustainability across farm types. In addition, the land capability profile of Scotland suggests that production is quite polarised by bio-geographic factors. In this way ‘hotspots’ for intensification can be identified across the cropping and lowland livestock practices of the East Coast and the dairying enterprises in the South-West. Conversely, the less favoured areas of Scotland provide a series of market and non-market benefits but may benefit from an alternative approach to managing and supporting development towards sustainable intensification.

- **Adoption of sustainable intensification practices may require new approaches for advice and engagement**

Most farmers are continually adapting their systems to meet weather, biophysical, economic and policy related factors. These changes be classified as changes in machinery, labour and resource use. The process of intensification itself implies the adoption of a technology to manage change within a system. Accordingly, encouraging adoption of new technologies which offer multiple ‘non-farm’ type benefits may require different approaches towards engagement. Most studies find a mixture of financial and non-financial factors which dictate adoption. Thus, whilst policy ambitions may change to encourage sustainable intensification, the key actors within the framework may be reluctant to adopt these production trajectories due to lifestyle and other factors.

- **Much further work is needed to understand sustainable intensification issues within Scotland**

We suggest a number of areas are needed for future research within this field, namely i) linking data sets to gain a better picture of change over time; ii) using more participatory approaches to appreciate the level and perception of sustainable intensification within members of the supply chain, including the consumer iii) developing multidisciplinary working on this topic to gain insights into how to measure some of the multi-faceted aspects of sustainability and intensification; and iv) examination of behavioural change within the farming context and how farmers, and indeed Scottish farming, can be nudged towards the adoption of practices which meet the multiple needs of present and future societies.
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1.0. Sustainable intensification within agriculture

1.1. Underlying rationale
Intensification of agricultural activity has been the main cause of loss in the range of ecosystem services provided by UK agriculture (Firbank et al., 2011). The notable exception has been the yield provisioning function of agriculture which, since the Second World War, has improved substantially.

The main drivers of this yield growth have been increases in productivity (Thirtle et al., 2003; Barnes et al., 2010). Future economic and social changes suggest that intensification of agricultural production is still an option for the management of agriculturally dominant landscapes. Influential policy and academic circles are beginning to explore the concept of ‘sustainable intensification’ (Ambler-Edwards et al. 2009; FAO, 2010; Jaggard et al. 2011). This concept aims to meet the multiple aspirations of society, in terms of securing and increasing yield, as well as the functional and cultural benefits that society values, e.g. protecting and enhancing bird species abundance.

There are also emerging global research and policy agendas based on the sustainable management of agricultural land and its synergies with the production of multifunctional benefits from these landscapes (Pretty et al., 2011; Foley et al., 2011) and 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.

The aim of this report is to provide the basis for understanding sustainable intensification within a developed country context, namely Scotland. The report is structured as follows. Initially sustainable intensification is defined and attempts made to reconcile this with Scottish policy goals for the Food and Drink industry to derive a Scotland specific definition. A conceptual approach to understanding sustainable intensification is then provided, focused on the issue of how to translate the technology of sustainable intensification to a specific Scottish context. The next section considers production within Scotland using standard Government statistics which enables consideration of the biophysical, structural and geographical parameters under which Scottish farming operates. Indicators of sustainability and intensification are then derived using the Farm Account Survey (FAS) data, which provides information on the characteristics of around 500 farms operating across Scotland and output potential is estimated using programming-based methods. The relationship between sustainability and intensification and possible indicators for sustainable intensification are discussed using the FAS and multivariate statistical techniques are applied to examine the relationships between these indicators. The final section offers discussion and conclusion points in terms of the policy implications and research questions which should be directed towards sustainable intensification issues within a Scottish context.

1.2. Defining Sustainable Intensification
It is important if we are to identify the potential for sustainable intensification to be clear on how it is defined. This concept aims to meet the multiple aspirations of society in terms of securing and increasing yields, as well as the benefits it values, such as protecting landscapes and wildlife. A common definition can be found below (Pretty et al, 2011):

*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* (Royal Society, 2009; Godfray et al., 2010).
Russell (2005) identified differences in definitions predominantly related to an economist’s and an ecologist’s view both of intensification and sustainability. This seems to boil down to a short term view and a long term view of how to achieve sustainable intensification. Within the economic literature, agricultural intensification involves increasing the use of inputs per hectare, but also encapsulates bringing in previously uncultivated land into cultivation or increasing the use of fixed costs, such as labour, and machinery on cultivated land. In the view of Russell, this implies ‘a short-run search for ways to increase variable inputs and output per hectare without compromising the integrity of the ecosystem within which production is embedded’. He goes on to highlight a longer term view, adopted by natural science disciplines, that defines intensification as any increase in inputs per hectare plus any increase in output per hectare whether or not it is accompanied by an increase in inputs. Broadly speaking, therefore, we will define intensification as:

‘.. an increase in output per ha through technology and best practice adoption, as well as an increase in material inputs to increase output per ha.’

1.3. The Scottish Policy context

The Government Economic Strategy, published in 2007, identified that the food and drink sector offers opportunities for growth (SG, 2007). This was embodied in the ‘refreshed’ Food and Drink industry strategy (Scotland Food and Drink, 2010). Principally this aims to grow industry turnover from £10bn to £12.5bn by 2017 and this would be achieved by focussing on ‘the global growth markets of premium, provenance and health’. This strategy mostly aims for growth through value-added processing.

The five strategic objectives of the Scottish Government (SG) are: to be ‘Greener’, ‘Safer and Stronger’, ‘Healthier’, ‘Wealthier and Fairer’, and ‘Smarter’ and the SG seek sustainable economic growth under these parameters. The focus is on a wider set of challenges, such as increasing skills and employment opportunities within the Food and Drink industry, the emphasis for the primary sector within this strategy tends to infer quality improvements rather than actual physical increases in output. SG strategies also strongly embed sustainability within the growth scenarios. The Food and Drink industry strategy understands the sustainability of Scotland’s food and drink industry to be:

‘..that we continue to make a healthy and growing contribution to the Scottish economy; and that by continuing to behave responsibly towards the environment we benefit our reputation and growth.’ (SG, 2010, pp. 6)

Scottish agriculture also operates within the framework European Union policy which is principally reflected in the Common Agricultural Policy (CAP). The CAP will be reformed in the near future and recent statements have promoted the continuation of a similar structure but with two main changes. First, the formal objectives of the CAP will reflect the priorities of ‘Europe 2020’ which, much more explicitly, promotes resource efficiency along with ‘smart, sustainable and inclusive growth’. Second, money will be diverted towards so-called ‘greening’ measures. This is currently under discussion and it is not clear exactly how agriculture will be greened under the new proposals. Nevertheless, this may provide a basis for joining the environmental aspects of the policy to production related goals within farming.

The focus on resource use efficiency at the EU level also allows some of the goals for the SG’s smart sustainable growth to be achieved and feeds into wider SG aspirations for reducing environmental impact. Hence, concentration on reducing waste within the production process helps to achieve commitments on water quality and also on climate change, through mitigating greenhouse gas emissions from reduced application of fertiliser, as well as increased efficiency within livestock production.
1.4. Dimensions of Sustainable Intensification

Generally, most policy and research towards farm management have supported a range of activity to generate ecosystems services from agriculturally dominated landscapes. This tends to be in the support of extensive activity, for example research finds that maintaining low stocking densities will encourage maintenance of nesting habitats and support for invertebrates. Other services from agriculture, such as the social value of maintaining landscapes are also higher under extensive, compared to intensive, management. However, recent policy relevant reports have highlighted concerns that farming activity has become too extensive leading to a potential loss of these ecosystems services. This is especially true in the hill and upland areas after decoupling of CAP support from production (SAC, 2008; Thomson, 2011). There is consequently an argument that in this situation intensifying activity, to prescribed levels, will support Scotland’s goals of sustainable growth.

Nevertheless, it seems that sustainable intensification is a difficult thing to wedge into current policy goals as the focus on improving the quality of the product may be compromised by increasing intensification. The main selling point of the Food and Drink Strategy is that Scotland promotes its natural assets and capital. A clearer route to sustainable intensification may rely on resource use efficiency, for example reducing wastage from over application of agro-chemicals into the system. The impact may be to improve outputs but is focused on improving the efficiency of inputs, which by implication reduces costs and thus supports economic sustainability within agriculture.

Accordingly, this report includes technical efficiency within its definition, which includes the changes in the relationships between inputs and output due to technology and process based advances, namely ‘adoptions of best practice as a means to achieving intensification which is sustainable’ (Russell, 2005).

Some thought is needed towards how sustainability could be defined. Sustainable intensification emerged from the ecological arena and, as such, policy and research documents seem to have a bias towards this area of sustainability. However, sustainability can cover a number of dimensions. Within the Scottish context we propose the following four dimensions which could be used a basis for understanding sustainability within agricultural intensification.
Thus **Economic sustainability** encompasses the income aspects of farming, covering both farmer and employer incomes, in terms of maintaining a sustainable level of income\(^3\). This implies that the maintenance of a fair standard of living is indicated by economic factors. Net Farm Income will also have effects on the long term sustainability of the system, through reducing debt ratios and maintaining capital to ensure efficiency of operation. For example a recent analysis of ‘uneconomic’ farmers has found that a number of producers are operating at low or negative levels of Net Farm Income and these are further characterised as having long term, and increasing, debt to asset ratios (Barnes et al., 2011).

**Social sustainability** embeds the impact of farming within the rural communities under which they operate. Most studies are now finding a decoupling of farm income from rural communities (in terms of the input output impacts), i.e. evidence of leakage of monetary payments. In addition, the social function of farming covers the production of food and further enhances its provenance. Growing consumer segmentation has led to a wide set of demands on aspects of food production which need to be addressed, ranging from income related (e.g. access to cheap food) to environmental and welfare related criteria that are deemed important to consumers.

Little work has been conducted on the **ethical dimensions of sustainable intensification.** Indeed, some commentators may not include this within a definition of sustainable. However, it should be considered within the Scottish context as, firstly, livestock produce is considered of high quality and the extensive production systems evident in Scotland may be a significant factor in providing a key attribute to defining Scottish produce. The growth in

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\(^3\) Notably here we could also include cost efficiency, but most studies focus on the changing physical relationships between inputs and outputs. Thus, farming income effects are imputed through the increasing technical efficiencies in the production process, but this ignores the supply chain aspects of sustainable intensification, in which input and output prices are distorted by relationships with suppliers and the retailers and the overall definition of sustainability may be biased against the producer, rather than in favour of the ecological and biophysical aspects of this definition.
intensity of production has to have an ethical dimension as the simple increase in stocking densities can increase incidence of disease and health issues, but also the achievement of greater yield per livestock unit may rely on a technology fix that could lead to harm within the production system, e.g. genomics for yield growth may have a negative impact on welfare factors.

**Ecosystem sustainability and intensification** is intrinsically linked with the biophysical capacity of primary inputs (MEA, 2005). The most comprehensively studied aspects of intensification have been the relationship with other ecosystem services (Firbank et al., 2011; Storkey et al., 2011). This literature has generated a wealth of sustainable management recommendations, including initial explorations of sustainable intensification itself (Pretty, 1995; Matson et al., 1997).

The noticeable reduction in the quality and structure of soil and other primary factors have been found to be a consequence of industrial agricultural methods. In addition, the increased carrying capacity needed to maintain yield growth has been generated by the application of chemical nutrients. However, there is growing evidence that plateaus have been reached in global yields, which are strong indicators of the limits to biophysical capacity (Licker et al., 2003).

Sustainable intensification must also be defined against a temporal background, and, indeed, is a significant factor for change within an agricultural system, as it encompasses the trajectory of ‘extensification to intensification’ just as much as the ‘unsustainable to sustainable’ trajectory. A graphic representing this conceptual approach is provided in Figure 1.2, and is illustrated with four possible trajectories for the agricultural industry, capturing sustainability criteria under intensification pressures.

These four pathways are:-

**A: Quick Start, Sustained Growth:** This is perhaps the most desirable for policy makers with short term goals as it implies a switch to technologies which offer quick rewards in terms of the differing dimensions of sustainability (Figure 1.1) but also improves as intensification rises. There will be some optimal point which is reached and is sustained as intensification rises, perhaps through development and adoption of further production focused technologies and techniques.

**B: Slow Start, Increasing Growth:** Much like the first trajectory, this offers benefits for the policy makers and society in general but encompasses low initial adoption and development of technologies which cross the paradigm of increasing intensification and sustainable growth. However, the successful adoption of these technologies will sustain growth and hence encourage uptake of sustainable practice.

**C: Post-Optimal Decrease:** This provides the reverse of B, offering quick short-term wins, through perhaps the uptake of technologies which already exist that provide so called win-win situations. However, this is not sustained through lack of results, investment in throughput of technologies or, more critically, achieving actual limits to yield growth. Hence, as intensification increases the damage levels increase.

**D. Failure to Launch:** Sustainable intensification may, like a number of technologies fail to be adopted as a practice on farms. Agriculture does provide a ‘graveyard’ of technologies which seem to offer benefits to both sustainability and intensification which have not been adopted. A great deal of behavioural work is being conducted on encouraging uptake, and this trajectory perhaps has the most prominent precedent within most developed country farming systems.
1.5. **Summary**

- Sustainable intensification has a strong level of support in policy circles as a means to meet the consumption needs of a growing population.

- Whilst it is a global desire, and certainly one that applies to developing countries, Scottish policy has a wider set of goals which may conflict with the requirement for intensifying production. Accordingly, definitions of sustainable intensification must have a regional focus.

- We propose that intensification within Scotland needs to meet four dimensions: economic; social; ecosystem; and ethical aspects, to be classed as sustainable intensification.

- Sustainable intensification implies a process over time; consequently when evaluating sustainable intensification a temporal dimension needs to be considered.
2.0. Data and Methods

2.1. Data
The aim of this research is to examine sustainable intensification. This implies a temporal change, as oppose to simply examining intensity within one time period. Hence, datasets are needed to explore how this may have changed over time. A number of datasets are available that meet this criteria. The principal ones are; i) the Farm Account Survey (FAS), which covers a sample of around 500 farms per year and offers detailed indicators on inputs, outputs and socio-economic data on the farms themselves; ii) the June Agricultural Census data, which covers all 50,000 holdings within Scotland and mostly offers information on production and areas; and iii) the Integrated Administration and Control (IACS) system data, which provides field level information for production for the 20,000 farms who claim a support payment. Furthermore, this dataset offers detailed information on uptake of environmental schemes under the Scottish Rural Development Programmes.

The FAS offers far more indicators of intensification than the others, however. Future work would align these data sets to provide geographically detailed information and would give a more detailed understanding of this and wider issues related to sustainable intensification.

2.2. Analysis
The Farm Account Survey provides time series data from 1989 to the most recent year (2010) and becomes more detailed as it progresses. The FAS data are collected yearly under EU FADN quality guidelines and using these data, indicators of intensification and sustainability were generated.

Data Envelopment Analysis (DEA) was used to estimate output potential against actual output as an indicator of the present gaps present within Scottish agricultural production. DEA uses a series of linear programming techniques to generate a ‘best-practice’ frontier, representing the best available performance within a sample set. This allows the distance from the frontier to be measured between these farms and the remainder of the farm set. Hence this is used to assess the potential output that could be achieved relative to actual output produced for Scottish agriculture.

The relationships between sustainability and intensification were estimated through simple correlation analysis. In order to reduce the size of the variables used, principal component analysis (PCA) was applied. This reduces the ‘dimensions’ within the data and identifies the key components within the data structure. The PCA therefore is used to identify different types of farms, based on sustainability and intensification characteristics. This is compared over time to provide a dynamic understanding over how change has occurred in Scottish farming.

4 Under the RESAS 5-year funded theme ‘Economic Adaptation’, the aim is to join the FAS with these other data sets.
3.0. Measuring the Productive Capacity of Scottish Agriculture

3.1. Output and Value of Scottish Agriculture
Scottish primary production accounts for £3.0 billion including support payments, of which 0.81 billion is from cropping activities and 1.26 billion from livestock and livestock products (again including support) (RESAS, 2010).

Figure 3.1 shows the improvement in the main cereal yields for the last 20 years in Scotland. Clearly there are some fluctuations, due to mainly weather events, but the trends are all upwards. Though notably there is some flattening of the growth rate in the latter years for cereals and spring barley.

**Figure 3.1. Increases in Scottish cereal yields, 1991 to 2010, tonnes per ha**

![Cereal Yields Chart](Source: RESAS, 2010a)

Total cereal yields have increased by 14% over this period, with barley increasing by 15% and wheat yields increasing by 10%. Though this rate of growth has slowed over time and is evidenced in the fitting of a slightly curved line, indicating that output growth has flattened rather than increased linearly.

Figures 3.2 and 3.3 show simple indexes for the main cropping and livestock products of agriculture.
All main cropping categories have fluctuated over this period but comparing 2001 to 2010 there have been increases in output. This ranges from just 2% for cereals to over 100% for raspberries and strawberries. These latter gains driven by the adoption of polytunnels which lengthen the growing season. However, fluctuation is quite large with some year showing significant dips from 2001 years indicating that climate and market factors still have a strong influence on crop output.

In contrast, within the meat sector most trends are downward, aside from beef. Again, there are policy factors leading to this, in terms of removal of specific supports for the other sectors, and the overall decoupling of production from subsidy payment (aside from beef which remains coupled).

3.2. Resource Use within Scottish Agriculture
Total inputs into Scottish agriculture amounted to £2.4 billion in 2010 (RESAS, 2010b). Of the main inputs into the production process, around 0.7 billion was accounted for by fertiliser and other nutrients, and 0.42 billion from rent (including imputed for owner occupied land), labour and interest payments. Figure 3.4 shows the total factor productivity (TFP) index for Scottish agriculture, which measures the rate at which inputs are converted into outputs (Barnes et al., 2011). It shows that whilst productivity showed early growth in the first part of the series from 1989, it then flattened in the mid-2000s and then declined. It appears that
CAP reform led to a reduction in output growth but total inputs have not adjusted correspondingly, which leads to slowdowns in the rate of TFP growth.

Figure 3.4. Total Factor Productivity Index for Scotland, 1989 to 2009

Table 3.1 shows the key indicators of total and partial productivity growth for Scotland across various time periods, reflecting policy changes from 1989 onwards.

<table>
<thead>
<tr>
<th></th>
<th>89-00</th>
<th>00-04</th>
<th>05-09</th>
<th>89-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP</td>
<td>1.0%</td>
<td>1.1%</td>
<td>-2.0%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Output Index</td>
<td>1.1%</td>
<td>0.1%</td>
<td>-1.9%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Total Inputs</td>
<td>0.1%</td>
<td>-1.0%</td>
<td>0.1%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Labour Productivity</td>
<td>2.0%</td>
<td>1.5%</td>
<td>-0.8%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Land Productivity</td>
<td>1.3%</td>
<td>0.1%</td>
<td>-1.7%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

Generally, most indicators show a slowdown in growth and these fall to negative levels in the latter period, which has impacts on the sustainability of the resource. Thus labour and land productivity have fallen over this whole period.

3.3. Measuring Output Potential Within Scottish Agriculture

The data envelopment analysis (DEA) technique was used to establish the level of output potential available given the fixed set of inputs used within the 2010 FAS sample. DEA is based on linear programming methods and can be used for understanding the maximum levels of output available, or the minimal levels of input needed to maintain output at a certain level.

An example is shown below for the value of cereal output in (£) relative to land area. The frontier represents optimal observed performance, i.e. those farms who are utilising their land optimally relative to the other cereal farmers within that sample. Clearly, there is a wide dispersion of results, for example some farms with a cropping land area in excess of 300 hectares are clearly quite distant from their peers.
Using this technique and adopting an output-maximisation orientation for the different farm types within the FAS gives some flavour of the output potential available if farms all adopted best practice techniques. This has been conducted for the main farming types within Scotland in Table 3.2 below.

Table 3.2. Mean actual and potential output from farms within the Farm Account Survey Scotland in 2010, £

<table>
<thead>
<tr>
<th>Farm Type</th>
<th>N</th>
<th>Actual (£)</th>
<th>Potential (£)</th>
<th>Difference (£)</th>
<th>Act /Ha</th>
<th>Pot/ha</th>
<th>Diff /ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>77</td>
<td>108,772</td>
<td>115,348</td>
<td>6,576</td>
<td>745</td>
<td>799</td>
<td>55</td>
</tr>
<tr>
<td>General Cropping</td>
<td>54</td>
<td>198,118</td>
<td>211,036</td>
<td>12,918</td>
<td>1027</td>
<td>1111</td>
<td>84</td>
</tr>
<tr>
<td>LFA Cattle &amp; Sheep</td>
<td>61</td>
<td>185,767</td>
<td>190,933</td>
<td>5,166</td>
<td>494</td>
<td>506</td>
<td>12</td>
</tr>
<tr>
<td>LFA Sheep</td>
<td>41</td>
<td>54,305</td>
<td>59,251</td>
<td>4,946</td>
<td>110</td>
<td>115</td>
<td>5</td>
</tr>
<tr>
<td>LFA Cattle</td>
<td>114</td>
<td>88,998</td>
<td>98,196</td>
<td>9,198</td>
<td>591</td>
<td>653</td>
<td>63</td>
</tr>
<tr>
<td>Dairy</td>
<td>51</td>
<td>63,545</td>
<td>71,263</td>
<td>7,717</td>
<td>491</td>
<td>544</td>
<td>54</td>
</tr>
</tbody>
</table>

* The lowland Cattle and Sheep sector only had 17 observations in 2010 which is too low for generating robust results.

Accordingly, it seems that on average, most firms have some opportunity for improvement. The differences in output potential compared to actual output range from £5 per ha for specialist sheep producers to £84 per ha for general cropping. However, though this difference is based on comparing against best practice farms there may be a host of

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* The low levels of observation for this group are an obstacle as this farm type is a likely candidate for intensification in the future.
underlying factors which constrain farms reaching the frontier, such as biophysical capacity, climatic factors and attitudinal or management differences within the farm decision-maker.

Within Scotland there are significant regional differences in production. Figure 3.6 compares the distribution of stocking densities by parish between 1997 and 2010 for cattle per hectare, taken from the June Annual Agricultural Census. This clearly illustrates the dispersed nature of intensity of agricultural production, with the ‘hot-spots’ of intensity covering the Eastern Coast and parts of the South-West.

**Figure 3.6. Cattle Grazing per hectare**

![Map showing cattle grazing per hectare in Scotland](image)

Table 3.3 shows the land capability assessment for Scotland. Land has been collapsed into four categories. These are presented below along with the respective areas and percentage of agricultural land within Scotland.

**Table 3.3. Land Capability within Scotland**

<table>
<thead>
<tr>
<th>Land capable of Supporting:</th>
<th>Grades</th>
<th>Area</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable Agriculture</td>
<td>1 - 3.1</td>
<td>625,800</td>
<td>8</td>
</tr>
<tr>
<td>Mixed Agriculture</td>
<td>3.2 – 4.2</td>
<td>1,541,100</td>
<td>20</td>
</tr>
<tr>
<td>Improved Grassland</td>
<td>5.1 - 5.3</td>
<td>1,405,700</td>
<td>18</td>
</tr>
<tr>
<td>Rough Grazing</td>
<td>6.1 - 7.0</td>
<td>4,035,800</td>
<td>51</td>
</tr>
</tbody>
</table>

Source: MLURI (2009)

The majority of agriculturally productive land can be found on the Eastern Coast, which provides mostly cropping. Stocking (grassland) is also on the Eastern Coast as well as the Southwest, which is traditionally seen as providing grazing land for dairy production. The North-West is the fragile area which perhaps produces the greater stock of environmental capital. These are typified by low stocking densities within sheep and cattle farming but also
demonstrate evidence of greater pluri-activities, and capture specific culturally valuable services from crofting.

The biophysical characteristics of Scottish agriculture means that the potential for output increases is highly varied across regions and the policy goals from these regions should differ according to geographic focus.

3.4. Summary

- Scottish agricultural primary production is only a small aspect of Scotland’s GDP output. However, the value to the supply chain, as well as associated cultural and social values from farming, are far higher.

- Scotland is constrained by quite polarised bio-geographic factors which will limit the potential for output growth from intensification. Nevertheless, ‘hot-spots’ could be identified within the cropping sectors, as well as lowland cattle and dairy enterprises of the Eastern Coast and South-West. Conversely, the increasing extensification of the hill and upland sheep and cattle farms tends to indicate that policy goals, related to output and sustainability should differ by geographic focus.

- Intensification is a clear driver of output growth but significantly not the only driver, as the characteristics of the farmer and the farm itself will determine how output trajectories develop.

- In these hotspots which have potential for intensification then, we need to understand how pursuit of output growth and input efficiencies can be more sustainable. The aim of the next chapter is to measure the relationship between sustainability and intensification.
4.0. Measuring sustainable intensification in Scotland

The purpose of this section is to attempt to outline a baseline for measuring sustainable intensification within the Scottish context. The four dimensions presented in Figure 1.1 are discussed and, where possible, indicators are presented from the FAS. Furthermore, indicators of intensive production are also discussed in order to understand how intensification has developed over this period and the underlying potential that exists for growth in the system. It is important to note the observation of Dietrich et al (2010), that a number of indicators exist for measuring land use intensity, but fewer studies define land use intensification, that is the process of an increase in land use intensity. Accordingly, by tying the analysis to secondary data collected annually some indication of the temporal dimensions of sustainable intensification can be provided.

4.1. Generating indicators of intensification

Within Scotland a large proportion of farms (51%) manage less than 10 ha of agricultural land (RESAS, 2011). Conversely, 9% of total holdings are greater than 200ha in size where, it would be expected, that more intensive agricultural practices would be found.

Table 4.1 has been produced by the SG (2012) using farm account data for 2008 and applying a Eurostat comparator based on projecting an EU average in 1995 on main variable inputs (fertiliser, feed and seeds) per ha. Hence, it measures intensification relative to an EU average. This has also been classified by particular types expected to be affected by future CAP reform.

<table>
<thead>
<tr>
<th>Farm Type</th>
<th>Low Intensity</th>
<th>Medium Intensity</th>
<th>High Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>0</td>
<td>79</td>
<td>21</td>
</tr>
<tr>
<td>General Cropping</td>
<td>0</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>LFA Sheep</td>
<td>86</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>LFA Cattle &amp; Sheep</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LFA Cattle</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>LFA Mixed</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>LFA Dairy</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Non-LFA Dairy</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Lowland Cattle &amp; Sheep</td>
<td>0</td>
<td>31</td>
<td>69</td>
</tr>
<tr>
<td>Non-LFA Mixed</td>
<td>0</td>
<td>16</td>
<td>84</td>
</tr>
</tbody>
</table>

Source: (SG, 2012)

Notably, the majority of LFA cattle and sheep farms are deemed low intensity, whereas the bulk of cropping and beef farms are medium intensity and specialist dairy and mixed livestock enterprises are deemed highly intensive already.

Figure 4.1. shows the number of cows on farms within the FAS over the period 1989 to 2010 as a boxplot. This presents a graphical output of the median value and the variance around that value. In addition, it gives some indication of the outliers, namely those farms which have extremely high or low values.

6 Though notably, if we included Horticulture within this definition, then intensity and size may not be as strongly related.
The median number of cows has had little fluctuation, remaining at 75, throughout the whole of the period. Since 2005 there seems to be an increasing number of outlier farms, which suggest that some farmers in the wider population have been increasing animal numbers since decoupling.

**Figure 4.1. Boxplots of median cows by year**

The simplest measure of intensification in the livestock sector is a ratio of output to a particular input, such as grazing livestock units\(^7\). Figure 4.2. shows stocking densities per farm type, that is the mean grazing livestock units (GLU) per hectare of grassland and rough grazing over the period 1989 to 2010.

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\(^7\) Grazing livestock units is the result of multiplying all animals on a farm by a corresponding conversion factor related to their grazing intensity. These can be found in the SAC Farm Management Handbook.
On the whole, stocking densities have slightly increased for some sectors over the period, mostly for the mixed and dairying categories, and the remainder have experienced falls. Since 2000, Less Favoured Area (LFA) cattle based categories have declined, perhaps due to changes in payment mechanisms, which has led to destocking to meet environmental criteria.

The most intensive sector is dairying and Figure 4.3 shows stocking densities for all dairying livestock units, indicating medians, ranges and outliers. Density has increased at the median, and in addition, more intensive outlier farms seem to have emerged over this period, with some reporting stocking densities of around 5 livestock units per ha.
Figure 4.3. Box plot of stocking densities for specialist dairy farms, 1989 to 2010

Figure 4.4. shows the spread of the cost of fertilisers and crop protection products to cropping area for specialist cereals and general cropping\(^8\). The input intensity does not seem to have increased over this period for the majority of cropping farms, however there seems to be a consistent set of outlier farms operating at much higher levels of input use within the system.

\(^8\) The FAS does not report quantities of fertiliser applied but converting into constant prices reflects the changes in quantities may reduce some of the variability inherent in price changes.
In 1989 this was at £189 per ha and ends in 2010 at its highest of £220 per ha (in 2000 prices). This seems to indicate that, taken as a static change over this period, cereal farming has become more intensive. However, there is significant fluctuation across years and also across farms, with wide interquartile ranges and a number of outliers on both the extensive and intensive side of the box plot. In addition, recent years have seen farmers respond to increasing output and input prices which may have affected management decision-making.

Table 4.2 shows these intensity factors by farm type, in terms of the (somewhat arbitrary) comparison between the start of the series (1989) and (2010). A one-way anova test was used to measure whether these had changed over time and found no significant differences at the 0.05 level. This may reflect the changes in policies over this time which has not encouraged intensive practices.

Table 4.2. Differences in Intensity Factors for Main Farming Types, Scotland, 1989 – 2010 (2000)

<table>
<thead>
<tr>
<th>Farm Type</th>
<th>1989</th>
<th>2010</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals (£/Ha)</td>
<td>183.69</td>
<td>220.16</td>
<td>36.47</td>
</tr>
<tr>
<td>General Cropping (£/Ha)</td>
<td>218.57</td>
<td>257.05</td>
<td>38.49</td>
</tr>
<tr>
<td>Dairy (SD/Ha)</td>
<td>2.10</td>
<td>2.28</td>
<td>0.18</td>
</tr>
<tr>
<td>LFAC (SD/Ha)</td>
<td>1.21</td>
<td>1.13</td>
<td>-0.08</td>
</tr>
<tr>
<td>LFAS (SD/Ha)</td>
<td>0.79</td>
<td>0.58</td>
<td>-0.21</td>
</tr>
<tr>
<td>LFACS (SD/Ha)</td>
<td>0.22</td>
<td>0.20</td>
<td>-0.03</td>
</tr>
<tr>
<td>LOWCS (SD/Ha)</td>
<td>2.20</td>
<td>1.67</td>
<td>-0.53</td>
</tr>
<tr>
<td>Mixed (SD/Ha)</td>
<td>1.68</td>
<td>1.84</td>
<td>0.16</td>
</tr>
</tbody>
</table>

9 This is because the FAS data are unbalanced. A Bonferri multiple comparison test was used to compare changes across different years.
In order to explore changes over time, the intensity factors within each farm type were split into three categories, namely low, medium and high intensity. This was based on taking the lower and upper quartiles across the whole time series. Consequently, it presents a relative comparator of change which is farm type specific and indicates how intensity compares over the time period. Table 4.3. shows the frequency of membership for the 7 farm types across the three intensity criteria.

<table>
<thead>
<tr>
<th>Farm Type</th>
<th>1989 Low</th>
<th>1989 Medium</th>
<th>1989 High</th>
<th>2010 Low</th>
<th>2010 Medium</th>
<th>2010 High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>23.5</td>
<td>55.9</td>
<td>20.6</td>
<td>11.7</td>
<td>36.4</td>
<td>51.9</td>
</tr>
<tr>
<td>General Cropping</td>
<td>20.4</td>
<td>51.9</td>
<td>27.8</td>
<td>11.1</td>
<td>59.3</td>
<td>29.6</td>
</tr>
<tr>
<td>Dairy</td>
<td>32.3</td>
<td>45.2</td>
<td>22.6</td>
<td>21.6</td>
<td>39.2</td>
<td>39.2</td>
</tr>
<tr>
<td>LFAC</td>
<td>26.5</td>
<td>52.9</td>
<td>20.6</td>
<td>36.0</td>
<td>48.2</td>
<td>15.8</td>
</tr>
<tr>
<td>LFAS</td>
<td>22.4</td>
<td>52.3</td>
<td>25.2</td>
<td>32.8</td>
<td>55.7</td>
<td>11.5</td>
</tr>
<tr>
<td>LFACS</td>
<td>27.8</td>
<td>54.2</td>
<td>18.1</td>
<td>24.4</td>
<td>61.0</td>
<td>14.6</td>
</tr>
<tr>
<td>LOWCS</td>
<td>16.7</td>
<td>58.3</td>
<td>25.0</td>
<td>47.1</td>
<td>41.2</td>
<td>11.8</td>
</tr>
<tr>
<td>Mixed</td>
<td>31.7</td>
<td>45.0</td>
<td>23.3</td>
<td>30.4</td>
<td>42.0</td>
<td>27.5</td>
</tr>
</tbody>
</table>

What emerges is that some farm sectors have experienced quite stark changes in membership of the high intensity group. For example, 52% of cereal farms are now in the high intensity group compared to only 21% in 1989. Nearly 40% of dairy farmers are in the high intensity category compared to 23% in 1989 and there have been some slight increases in the mixed group as well. However, what is also notable is the reductions in membership of this group within the cattle and sheep sectors. In some cases membership has nearly halved, which has bolstered either the medium intensity group or the lower intensity groups. A caveat to this approach is that the FAS are an unbalanced panel, that is some farms enter and leave the survey over time and, though efforts are made to make the panel robust, there may be some fluctuation simply due to changes in membership.

The figures and tables within this section therefore present a mixed picture of how Scotland has changed in terms of land use intensity. Moreover a temporal dimension reveals that intensification has fluctuated quite considerably through combined mechanisms of market prices, and changes in subsidy payments and requirements.
4.2. Generating indicators of sustainability

A small number of studies have attempted to generate indicators of sustainable intensification, the most relevant being Ripoll-Bosch et al. (2012). These authors used a combination of secondary and primary data and on-farm monitoring to develop indicators of sustainability. They used a framework, MESMIS, which recognises sustainability across 7 different dimensions, namely: (a) **productivity** (capacity to provide the required level of goods and services); (b) **stability** (ability to maintain a constant level of productivity under normal conditions); (c) **reliability** (maintaining productivity at levels close to equilibrium under normal environmental shocks); (d) **resilience** (return to equilibrium or productivity levels similar to the initial level after serious disturbance); (e) **adaptability or flexibility** (ability to find new levels of balance or to continue offering benefits to long-term changes in the environment); (f) **equity** (a system’s ability to distribute both intra- and intergenerational benefits and costs fairly); (g) **self-reliance** (system’s ability to regulate and control interactions with the outside).

However, the bulk of their indicators were collected through primary data and perhaps provide a basis for developing a research study within Scottish agriculture. This is not the ambition of this study, as we are firstly tied to secondary data, and secondly wish to examine changes over time, i.e. intensification rather than intensity. Because these data haven’t been yet matched with other sources (such as IACS and the JAC) we must search the FAS for some proxies of sustainable intensification. Thus, what follows is an admittedly pragmatic approach with the view to presenting topics for discussion in how indicators could be collected under the four dimensions of sustainable intensification proposed for Scottish agriculture.

It should be noted that some more detailed indicators are available in the latter survey years and could be useful for going forward. However, we aim to examine intensification over the whole period that we are concerned with (1989-2009). Hence the choice of indicators is limited to variables that are available in the 1989 survey and have been consistently collected throughout the whole period. Second, in order to provide consistency in analysis, data were rescaled so that they run on a continuous scale from 0 (bad) to 1 (good).

4.2.1. Ecosystem Indicators

Table 4.4 shows the variables that may give some indication of change in supply of ecosystem services from the FAS, the principal one being the level of rough grazing area to total area. This has been used as a criteria for identifying Higher Nature Value farming systems (Barnes et al., 2011) and thus presents a useful proxy for generation of ecological habitats. Similarly, total farmed woodland to total area presents another dimension to this, as this may provide a wider range of habitats for species which exist within the landscape and, indeed, loss of area to agricultural production, would indicate loss of this diversity of service. Finally, the ratio of permanent to temporary grassland is an important indicator for Scotland as permanent grassland represents a stronger level of lock-in of carbon and soil structure compared to temporary grass. Hence, changes in the relative area of these two can give some dimension on the ecological and climatic value of this natural stock and, indeed, is strongly related to the intensity of livestock production.

A further three variables are added which reflect dimensions of biophysical stress within the system (and hence damage to natural capital). Long-term productivity (which encapsulates the process of conversion of inputs to outputs) can be measured by examining output growth relative to input growth. In addition, specialisation of production reflects an increase in mono-production and the loss of species diversity that emerge from a mixed farming system. This latter indicator, however, is fraught with difficulties as we must weigh the ecological services higher than the yield provision services that come from specialisation within the
system itself. Nevertheless, it is one of the few indicators available that captures cropping intensification and sustainability from within the FAS.

### Table 4.4. Proposed Indicators of ecosystem aspects of sustainable intensification

<table>
<thead>
<tr>
<th>Variable</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGA</td>
<td>Total Rough grazing Area / Total Area</td>
</tr>
<tr>
<td><strong>Rationale</strong></td>
<td>Rough grazing is reflective of the biodiversity mix relative to managed agricultural land. Higher levels of rough grazing per total area leads to increased biodiversity and related improvements.</td>
</tr>
<tr>
<td>WGA</td>
<td>Total (farmed) woodland area to total area</td>
</tr>
<tr>
<td><strong>Rationale</strong></td>
<td>Indicative of managed woodland and hence greater biodiversity capture. Higher levels of woodland would lead to greater mixes of biodiversity and carbon capture.</td>
</tr>
<tr>
<td>TPG</td>
<td>Ratio of permanent to temporary grass area</td>
</tr>
<tr>
<td><strong>Rationale</strong></td>
<td>The level of permanent grass area reflects maintained soil structures and preserves carbon sinks effects. Higher levels of permanent grassland lead to greater carbon capture.</td>
</tr>
<tr>
<td>LANDPROD</td>
<td>Total output value to total area</td>
</tr>
<tr>
<td><strong>Rationale</strong></td>
<td>Indicator of land productivity. Higher levels indicate some preservation of the natural stock of biophysical capital.</td>
</tr>
<tr>
<td>SPEC</td>
<td>Value of livestock (or crop) output to total output (*)</td>
</tr>
<tr>
<td><strong>Rationale</strong></td>
<td>A proxy for specialisation of activity. Higher levels indicate less diversity in the resources for ecological preservation.</td>
</tr>
</tbody>
</table>

#### 4.2.2. Economic Indicators

The main purpose of the FAS is to examine financial changes within farming. Hence, a comprehensive range of factors can be found to demonstrate some aspects of economic sustainability. These range from debt factors (such as interest cover) to resilience factors (such as the level of subsidy within a system).

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10 For some indicators the inverse of the ratio was taken, this ensured consistency of measurement across the indicators. Where an inverse was taken in what follows a (*) symbol is attached.
Table 4.5. Indicators of economic aspects of sustainable intensification

<table>
<thead>
<tr>
<th>Variable</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTC</td>
<td>Interest cover to total debt (*)</td>
</tr>
<tr>
<td>Rationale</td>
<td>The level of interest paid to total debt is a proxy for financial stress. Higher levels of risk indicate more financial stress on the business.</td>
</tr>
<tr>
<td>SUB</td>
<td>Total subsidies to farm gross margins (*)</td>
</tr>
<tr>
<td>Rationale</td>
<td>Higher levels of subsidy burden mean less resilience within the business to market forces.</td>
</tr>
<tr>
<td>RE</td>
<td>Total rent and interest paid to farm gross margin (*)</td>
</tr>
<tr>
<td>Rationale</td>
<td>Reflects the burden of the land and machinery and building factors on profitability. Higher levels indicate financial stress within the business.</td>
</tr>
<tr>
<td>LABC</td>
<td>Total costs of paid labour to gross margin (*)</td>
</tr>
<tr>
<td>Rationale</td>
<td>This reflects the amount of the external labour on profitability. Higher levels indicate more financial stress within the business.</td>
</tr>
<tr>
<td>CONT</td>
<td>Total costs of contracting to total variable costs (*)</td>
</tr>
<tr>
<td>Rationale</td>
<td>This reflects the amount of total contracting within the cost profile of the farm business. Higher levels indicate a higher burden on the farm business.</td>
</tr>
<tr>
<td>ECONEFF</td>
<td>Total output value to total fixed and variable costs</td>
</tr>
<tr>
<td>Rationale</td>
<td>This reflects the efficiency within the farming business of converting total costs to total output. Higher levels indicate higher levels of efficiency.</td>
</tr>
</tbody>
</table>

4.2.3. Social Indicators

In capturing social aspects of sustainability, a number of factors related to on-farm work can be derived. However, such aspects as rural impact can only be hinted at through these indicators, as they can reflect both the numbers of non-family farmers, but also the levels of diversification within the farming enterprise.

Table 4.6. Indicators of social aspects of sustainable intensification

<table>
<thead>
<tr>
<th>Variable</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABFAMIX</td>
<td>Total farmer hours to total hours worked (*)</td>
</tr>
<tr>
<td>Rationale</td>
<td>Indicator of farmer work intensity relative to total farm hours needed</td>
</tr>
<tr>
<td></td>
<td>Higher levels indicate increasing stress</td>
</tr>
<tr>
<td>HIRDMIX</td>
<td>Total hired labour to total hours worked</td>
</tr>
<tr>
<td>Rationale</td>
<td>This indicates the amount of external labour entering the farm. It therefore provides a proxy for rural income opportunities and income generation.</td>
</tr>
</tbody>
</table>

Notably, other indicators could be explored such as the ratio of farm business income to net farm income, however this is only available from 2008 onwards and therefore is disregarded within this study. Other factors considered were age related, namely farmer and partner ages which would reflect some element of innovation and succession. The literature on this is mixed and hence no definite impact of age could be used to assess social sustainability.

4.2.4. Ethical indicators

No ethical dimensions could be found through the FAS. Suggested variables were related to cow yield or feeding rates, which may be a proxy for ethical treatment of animals. However, this is probably not the case as the management of the animal is a significant factor in meeting ethical desires regarding welfare and these are not measured in the FAS. Some studies have collected on-farm data and reconciled this against farm management.
4.3. Reconciling sustainability with intensification indicators

4.3.1. Weighting indicators
Key decisions are how to weight the various dimensions of sustainable intensification and also the indicators themselves within the various dimensions. For example, food production is presented within the ecosystem dimension through land productivity. Food production related issues have had an interesting and fluctuating influence on policy makers throughout the last twenty years. In 1989, it could be argued from a policy perspective that food production was the central concern of farming, as both the EU and UK were promoting output expansionist policies. However, society was becoming increasingly critical of the loss of environmental quality at the public expense of generating output surplus from these policies.

Furthermore, the ethical dimension is a critical aspect of understanding change over time, as perceptions of animal welfare and, overall equity, within the food production system have grown. Under intensification scenarios this is critical as, if food scarcity increases, then perhaps ethical considerations are reduced. Consequently, there is an element of future uncertainty that could be mapped within, perhaps, a textual analysis of documents related to agriculture. This may provide a dimension on how weighting of demands from agricultural production would change. Ripoll-Bosch (2012) used workshops to generate weightings on a farm by farm basis, which is perhaps the correct approach. Nevertheless for an exploratory study such as this we rely on an objective and quantitative approach to reducing the numbers of variables within the data, that is principal component analysis (PCA).

Accordingly, we take the indicators generated for intensification and sustainability and reduce their dimensions by PCA methods. The importance of variables, representing social, economic and ecosystem sustainability and intensification over time are revealed within this approach.

4.3.2. Simple Correlations
Table 4.7 shows the results of a simple correlation analysis between the different aspects of sustainability against intensification across the farming types, with only the values presented for those that are significant at the 5% level.
Table 4.7. Significant correlations between sustainability and intensification factors, by farm type, 1989-2010 dataset

<table>
<thead>
<tr>
<th></th>
<th>Cereals</th>
<th>GenCrop</th>
<th>Dairy</th>
<th>LFAC</th>
<th>LFACS</th>
<th>LFAS</th>
<th>Mixed</th>
<th>LowCS</th>
</tr>
</thead>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>-0.40</td>
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<td>-0.64</td>
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<td>-0.27</td>
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<tr>
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<td></td>
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<td>-0.12</td>
<td>-0.14</td>
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<td></td>
</tr>
<tr>
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<td>0.69</td>
<td>0.64</td>
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<td>0.71</td>
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</tr>
<tr>
<td>SPEC</td>
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<td>0.15</td>
<td>-0.12</td>
<td></td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Economic</strong></td>
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<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>EEF</td>
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<td>-0.07</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Social</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.12</td>
<td>0.18</td>
<td>0.28</td>
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</tr>
<tr>
<td>HIRDMIX</td>
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<td>-0.13</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

4.3.3. Principal Components Analysis

The principal components analysis (PCA) approach allows a reduction in the number of variables by explaining the variance within the data. A PCA was estimated for each farm type using the variables outlined above. Standard statistical tests found five components present in the data across all farm types, one of which included the intensification variable within the component score loadings. Hence, we find for each farm type a **sustainable intensification component** (SI component) exists. The characteristics of this component are best shown as a web-diagram, which gives the mean scores by each farm type.
Scores across the different indicators fluctuate by farm type, but the majority have high scores for the land productivity variable (which represents preservation of the biophysical capacity of farms). However, only lowland cattle and LFA cattle and sheep farms have prominent scores on the labour aspects of sustainable intensification, namely the social dimensions related to mixtures of labour and the costs of external labour from the economic dimensions.

If we are to obey the rule that sustainable intensification must satisfy all four dimensions as presented in Figure 1.1, high scores across all these variables would be required. This does not seem to emerge from this analysis (albeit subject to a number of caveats related to the limited scope of the data). Hence, the above figure may give some indication of aspiration for future policy and research development in sustainable intensification. Namely, farms are under-represented on the economic and ecological aspects, and this may require further investigation to improve this.

In order to analyse membership of the sustainable intensification component over time, the PCA scores for the SI component were divided into three percentiles (high, medium, low). Then the proportion of those farms in the top percentile (high scores) were compared with the total population. This gives some indication of how many farms were deemed to have characteristics of sustainable intensification (in terms of the limits defined in Figure 4.5 above) over time.
Clearly there is significant fluctuation across time for this component. With most sectors having higher proportions of membership in the earlier compared to the latter period. Notably, as outlined in Section 3, intensification does not increase for most sectors over this period and in some cases starts to decline, which may be driving this result.

Finally, in order to determine the drivers of membership for the SI component a logistic regression was conducted on the key characteristics of the farms. This measures the odds of becoming a member of the SI component group. Thus, if these odds are higher than 1 then they are more likely to predict membership of the SI component. If they are less than 1 then the odds of being a member of this group are less than the odds of being a member of another component which does not include intensification.

**Table 4.8. Odds-ratios for membership of sustainable intensification component, by farm type**

<table>
<thead>
<tr>
<th></th>
<th>Cereals</th>
<th>GenCrop</th>
<th>Dairy</th>
<th>LFACS</th>
<th>LFAC</th>
<th>LFAS</th>
<th>LOWCS*</th>
<th>Mixed</th>
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</thead>
<tbody>
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<td>*</td>
<td>0.94</td>
<td>***</td>
<td>0.97</td>
<td>0.99</td>
<td>-</td>
</tr>
<tr>
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<td>**</td>
<td>0.52</td>
<td>***</td>
<td>0.78</td>
<td>*</td>
<td>0.96</td>
<td>-</td>
</tr>
<tr>
<td>ten</td>
<td>1.23</td>
<td>*</td>
<td>1.14</td>
<td>-</td>
<td>1.20</td>
<td>*</td>
<td>0.97</td>
<td>-</td>
</tr>
<tr>
<td>fage</td>
<td>0.97</td>
<td>***</td>
<td>1.02</td>
<td>*</td>
<td>1.01</td>
<td>*</td>
<td>1.01</td>
<td>*</td>
</tr>
<tr>
<td>page</td>
<td>0.81</td>
<td>-</td>
<td>0.85</td>
<td>-</td>
<td>1.11</td>
<td>-</td>
<td>0.48</td>
<td>***</td>
</tr>
<tr>
<td>gend</td>
<td>0.88</td>
<td>-</td>
<td>1.70</td>
<td>-</td>
<td>1.69</td>
<td>-</td>
<td>0.43</td>
<td>**</td>
</tr>
<tr>
<td>awu</td>
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<td>-</td>
<td>1.75</td>
<td>*</td>
<td>0.80</td>
<td>-</td>
<td>0.51</td>
<td>**</td>
</tr>
<tr>
<td>sgm</td>
<td>1.00</td>
<td>-</td>
<td>1.00</td>
<td>**</td>
<td>1.00</td>
<td>-</td>
<td>1.00</td>
<td>***</td>
</tr>
</tbody>
</table>

**Key:**
- Time = an index of years, with 1989 = 1...22
- Size = Size category of farm (1= small...3=large)
- Ten = Tenure status = 1 O-Occupied; 2 Tenant; 3 Landlord/Tenant Partnership; 4 Mixed
- Fage = Farmer age
- Page = ratio of 1st partner to farmer age
- Gend = Gend (0 = Male, 1 female)
- AWU = Total number of worker units
- SGM = Standard gross margins

The time variable is only significant for mixed, dairying and general cropping farms. These odds ratios are just below one, indicating that as the years have progressed there is less
chance of farmers entering the SI component. This tallies with Figure 4.6. which shows membership has declined over time.

For most farms the significant factors are size and farmer age. The size category tends to be below 1, aside from the LFA types. Hence, larger farms are more likely to be in the SI component in the LFA farms, whereas large farms in cropping and dairying categories are more likely to not be in this group. Age tends to fluctuate around 1, i.e. older farmers have marginally more or less chance of being members of the SI component group. In addition tenure is above 1 where significant. Hence, non-owner-occupiers are more likely to be in the SI component in cereal, dairy and LFA cattle and sheep specialist farms (though, less likely in the mixed farming groups). Gender is insignificant, aside from dairying where female farmers are less likely to be in the SI component. The total number of workers on the farm is not significant, aside from Cattle and Sheep enterprises. This indicates less chance of membership if the numbers of farm workers is high. Conversely, general cropping farms indicate that higher numbers of workers increases the chances of being in the SI component. The standard gross margin indicates no influence on membership of these groups, as they all round to an odds-ratio of 1, i.e. chances are the same across the SI and non-SI components.

4.4. Summary

- This chapter has attempted to reconcile sustainability variables with intensification indicators and measure actual progress towards sustainable intensification using real farm data.

- A mixture of positive and negative correlations between sustainability factors and intensification indicators exist.

- Land productivity, reflective of biophysical capacity, seems to be strongly related to intensification variables for most farms. The ratio of rough grazing to total grazing area, reflective of ecological generation, is negatively related to intensification.

1. Each farm type has farms with a component related to sustainable intensification (SI component)

2. Actual performance shows a strong link across the biophysical indicators and, in the case of cattle and sheep enterprises, with social and financial indicators related to labour profiles.

3. However, other dimensions related to ecosystem, financial and social dimensions of sustainable intensification are under-represented in the Scottish data.

4. Membership of the SI component has reduced over time. Size and tenure seem to be key factors which lead to a higher chance that a farm may enter the SI component group. Owner-occupiers are less likely to be in this group, as are farms which are bigger. However, for LFA farms this is reversed, with the bigger farms more likely to be in this group, probably due to the labour and grazing mixtures demonstrated on these farm types.
5.0. Discussion

Sustainable intensification has a strong level of international and national policy support as increases in output are needed to secure future food supplies. The academic arena has begun to explore how to define sustainable intensification within particular agricultural systems and technologies are being developed which attain these goals. In order to make this relevant to Scotland a number of areas need to be discussed and pursued to provide further insight into this issue.

- **We need to agree on a definition of sustainable intensification for Scotland**

To be truly sustainable, we suggest, intensification of agricultural production within the Scottish context requires four dimensions to be met, namely:

1. it must maintain equity in incomes throughout the supply chain and across producers; specifically a fair return throughout the supply chain;
2. it must strengthen the resilience of rural communities and maintain nutritional standards;
3. it must maintain or enhance the stock of Scotland’s natural capital and the flow of ecosystem services emerging from this stock; and
4. it must maintain or enhance the ethical dimension of agricultural production. This seems to be an underexplored area of sustainable intensification, which should include the treatment of animals under intensification systems, but also encompasses land ownership issues and access to land.

Defra have recently abandoned the term ‘sustainable intensification’\(^{11}\) to embrace the term ‘climate smart agriculture’. The FAO defines this as ‘an agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation) while enhancing the achievement of national food security and development goals.’

The requirement for ‘an agriculture which sustainably increases productivity’ would seem to encompass sustainable intensification strategies, and the four requirements above still hold to justify the sustainable dimension. However, the focus away from intensification shies away from the fact that we will have a limited amount of land to produce food on. Productivity is a loose term which allows for increasing levels of inputs into the production process, including land. As long as the rate of output is higher than the rate of input into the production system then productivity grows. Hence the focus needs to be on supply chain issues which address the quality and quantity of inputs into the production process. Finally, we argue that if any definition of sustainable intensification were adopted within Scotland, and for that matter any country, then some ethical debate is required over the treatment of people, land and animals to gain any higher output potential. Arguably, climate smart agriculture becomes a more nebulous term, and may mask some of the underlying debates surrounding how to sustainably feed a growing population.

- **We need to develop measures of sustainable intensification**

Measuring sustainable intensification presents both conceptual and measurement difficulties. It is no inconsiderable task to ensure that progress is being made towards increased sustainability, whilst also reconfiguring a farming system towards more intensive production.

\(^{11}\) We assume because of the negative connotations of intensification within public perceptions.
This firstly requires appropriate monitoring. Whilst the FAS provides indicators of input usage, it does not provide any spatial focus, nor activity at field or system level. Other data sets, such as IACS and census data, could be merged with the FAS to provide a clearer picture on sustainable intensification. However, the intricacies of sustainable intensification could only be captured through detailed on-farm assessments over time which, naturally, has cost associations for policy makers. Secondly, strong multi-disciplinary working is needed to set measurement goals. If the four dimensions outlined above are adopted it infers that ecologists should work in conjunction with sociologists, economists and even ethicists, as well as perhaps wider disciplines, to ensure that these dimensions are fully captured within the measurement process. Furthermore, it requires greater understanding of how to reconcile the (sometimes conflicting) indexes of sustainability and intensification which requires methodologies to extract weightings for individual indexes over different farming landscapes and, also, over time.

In an attempt to approach this question we have applied actual farm data to see where farms can be placed along the four dimensions of sustainable intensification suggested above. In reconciling these indexes we find a link between intensity and land productivity for most farms. Most farm types generated low scores on the other dimensions of sustainable intensification. Only LFA and Lowland cattle systems had reasonable scores towards the social and financial aspects of sustainable intensification, related mostly to the labour profile on these farms. Nevertheless, this may indicate where gaps need to be addressed within policy making if it were decided to pursue a policy of encouraging sustainable intensification.

Further work is needed to merge data sets and reconcile disciplines to truly measure progress. An interesting example of this is the engineering approach applied to intensive poultry and pig units (http://www.rondeel.org/) whereby buildings and systems practices are developed with input from a range of disciplines, such as architects, social scientists, animal welfare scientists and psychologists to understand how intensification paths can be followed which are more socially acceptable.

- **There seems to be no direct support for sustainable intensification within the policy literature**

Scottish policy does not seem to support increases in output but focuses more on quality and adding value within the supply chain. This includes the development of niche markets for products which have been underutilised within Scottish primary food production, such as venison and mutton, as a means of supporting output value growth. Furthermore, this focus on quality must align with issues related to diet and health problems within the Scottish population. Furthermore, intensification seems to be a clear driver of output growth or resource use efficiency. However, it is **not** the only driver. Farm production levels are the result of a complex nexus of present and future commodity prices, as well as production and non-production related subsidies; they also encompass attitudinal and behavioural underpinnings, as well as the bio-geophysical constraints of farming. Nevertheless, the increasing supply of produce, from an output-expansionist approach, would, all things being equal, lead to lower prices and, hence, lead to equity within consumption. Though, again, there are complex issues of maintaining equity within food commodity supply chains to achieve this.

The bulk of reviews dedicated to farming values tend to find strong support for the non-market effects of agriculture, such as landscape, ecological diversity and access to land. These tend to be exhibited in extensive systems, as oppose to intensive production. Accordingly, a policy is needed to reconcile the value added view of food and drink with sustainable intensification. The image of production intensification may clash with Scotland ‘the brand’ and the high price, high value consumer segments it supplies. Hence, caution is required. Participation is needed across the supply chain and consumer perceptions would
need to be changed, or assured that the quality of produce is not affected by the pursuit of sustainable intensification.

- **A regional approach to policy making may be needed, with corresponding indicators of success**

This study finds differences in indicators of intensification and sustainability across farm types. In addition, the land capability profile of Scotland suggests that production is quite polarised by bio-geographic factors. In this way ‘hotspots’ for intensification can be identified across the cropping and lowland livestock practices of the East Coast and the dairying enterprises in the South-West. Conversely, the less favoured areas of Scotland provide a series of market and non-market benefits but may benefit from an alternative approach to managing and supporting development towards sustainable intensification.

The bulk of Scottish farming land is designated a Less Favoured Area (LFA) and the SG has prescribed levels of minimum and maximum stocking densities to attain subsidies for this production handicap. Recent CAP reform has also led to a loss of production in certain areas, and the concerns of the SAC report ‘Retreat from the Hills’ (Thomson 2011), could be seen as a call for more intensive production (all be it from a highly extensive baseline). Hence, for the hill and upland areas of Scotland there is also a justification for exploring the potential for intensifying production to maximise the flow of ecosystem services from this valuable natural stock.

- **Adoption of sustainable intensification practices may require new approaches for advice and engagement**

Most farmers are continually adapting their systems to meet weather, biophysical, economic and policy related factors. These changes can be classified as changes in machinery, labour and resource use. The process of intensification itself implies an adoption of a technology to manage change within a system. Accordingly, encouraging adoption of new technologies which offer multiple ‘non-farm’ type benefits may require different approaches towards engagement. This is due to a complex history of subsidy payments diverting risk taking, the lack of opportunities for new entrants and the overriding influence of habits within farm decision making. A host of literature and interest is being directed at why farmers farm and their perceptions towards specific ecosystem service provision are being mapped (Defra 2008; 2011). Most studies find a mixture of financial and non-financial factors which dictate adoption. Accordingly, whilst policy ambitions may change to encourage sustainable intensification, the key actors within the framework may be reluctant to adopt these production trajectories due to lifestyle factors.

**Further Research Aspects**

This research is merely a discussion document using an appropriate data set to suggest how one would measure sustainable intensification. We have only just begun to explore the concepts and consequences of pursuing sustainable intensification, however. A number of suggestions are peppered throughout this report for increasing understanding of sustainable intensification. We suggest the following would be priority:

  i) Explore the possibility of linking up data sets to gain a greater understanding of the regional and biophysical aspects of sustainable intensification. Thus, temporal changes can be embedded in more realistic application of the SI concept.
ii) More participatory approaches to appreciate the level of innovation and indeed perception towards sustainable technologies and practices within the supply chain and the Scottish population generally. This includes how people view and define intensification of production itself, which can be a fluid concept across different strata of society and between farmers themselves.

iii) Increase multidisciplinary working on this topic to gain insights into how to measure some of the multi-faceted aspects of sustainability and intensification. This includes biophysical and social sciences, but may also gain perspectives from ethicists and psychologists to fully capture the sustainable intensification concept.

iv) Examination of behavioural change within the farming context and how farmers, and indeed, Scottish farming can be nudged towards adoption of practices which meet multiple societal needs.
References


