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Sustainable Intensification: A UK perspective

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Sustainable intensification (SI) is a term that has increasingly been used to describe the agricultural production systems that will be needed to feed a growing global population whilst ensuring adequate ecosystem service provision. However, key definitions of SI support quite different approaches; a report published by the Royal Society (Baulcombe et al. 2009) favours the land sparing model whilst a Foresight report (2011) favours land sharing. SI will require pragmatic and innovative policies, including further revision of the Environmental Stewardship Scheme and the development of landscape-scale governance within an over-arching strategic approach to planning. However, its innovation is its focus on unlocking the social at the expense of the private value of land (at those locations where non-market ecosystem services have a higher value than marketable agricultural products). Though scientific advances may help raise production efficiency through a better understanding of the trade-offs between agricultural production and ecosystem service provision, issues related to who controls the use of land will be the most difficult to resolve, which suggests a role for Boundary Organisational Theory (BOT) because of the insights this theory lends to negotiating complex problems. Within BOT terminology SI can be considered a "boundary object" about which stakeholders are able to negotiate site-specific issues to incrementally arrive at solutions which draw on the full range of land sharing and land sparing options and so avoid prescriptive approaches and technologies.

Keywords: agri-environment, land use, land sharing, land sparing, boundary object.

Introduction

The term sustainable intensification (SI) was initially used in the mid 1990s in the context of developing food production in Africa (Pretty 1997 ; Garnett and Godfray 2012). For example, "Strategic Objective A" of FAO Strategic Framework (2009-2025) is titled "The SI of crop production" (FAO 2010b: p1 & p7; FAO 2011). In the

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UK context the phrase perhaps first came to prominence in a report published by the Royal Society (Baulcombe *et al.* 2009). The notion of SI was taken up by the Foresight Programme. Created in 1994 to help the UK government think systematically about the future, it listed as one of “twelve key priorities for action for policy makers” in its “Global Food and Farming Future” study the need to “Promote sustainable intensification” (Foresight 2011 Box 8.1, p34).

The notion of SI was one of five core themes used by the European Union Agriculture, Food Security and Climate Change Joint Programme Initiative (FACCE JPI): “Environmentally sustainable growth and intensification of agriculture” (EUSAB 2010: p7). The UK’s Environment, Food and Rural Affairs Committee embedded a need for SI in their review of the 2013 reforms to the Common Agricultural Policy (CAP): “the aim for this round of CAP reform should be to enable EU farmers to achieve the ‘sustainable intensification’ that is required to meet the global challenges of feeding a predicted world population of 9 billion by 2050 without irrevocably damaging our natural resources”, (EFRA 2011: p23, para 64). In the following year the UK’s Commission on Sustainable Agriculture and Climate Change concluded that “Sustainable intensification is potentially the most promising means of simultaneously increasing food production while achieving land-based mitigation [of greenhouse gases (GHG)], as long as non-crop land uses such as forestry, grasslands or wetlands are able to sequester more carbon or emit lower levels of GHGs than cultivated land” (Beddington *et al.* 2012:p28).

So what is SI?

Baulcombe *et al.* (2009) in a report published by The Royal Society describes a SI system as one in which “yields are increased without adverse environmental impacts and without the cultivation of more land” (Baulcombe *et al.* 2009: p ix). This concept clearly interested the Foresight Global Food and Farming Futures project which, observing that many systems of food production were unsustainable (Foresight 2011:p 10), concluded that “sustainable intensification is necessary” (p 31). However, the Foresight report described SI as “simultaneously raising yields, increasing the efficiency with which inputs are used and reducing the negative environmental effects of food production” (Foresight 2011:p 34-35).

Common to both the Royal Society and Foresight reports is the need for SI to increase agricultural yields. However, they differ on how this should be achieved. Baulcombe *et al's* (2009) view is that this should not be at the expense of additional environmental degradation or of expanding the area for land farmed. The Foresight report goes further to suggests that existing levels of environmental impacts should be reduced and specifies that raised production of food should be achieved by more efficient conversion of inputs into outputs. Moreover, it specifies that these changes should happen simultaneously. It is silent about the prevention of extending the area of land farmed.

It should be noted that SI is one of several terms currently used to organise policy responses to the challenges of producing more food to feed a growing population at the same time as protecting and enhancing ecosystem service provision. The FAO also uses the term "climate-smart agriculture" (CSA) which it defines as "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals" (FAO 2010a: p ii). Godfray *et al.* (2010) have focused on the importance of reducing the "yield gap" (which is "the difference between realised productivity and the best that can be achieved using current genetic material and available technologies and management" (p 813)). Beddington *et al.* (2012) have developed the "safe space" concept, and a wide range of organisations and individuals support some form of agro-ecological farming, for example integrated pest management, agro-forestry, organic agriculture and conservation agriculture (CA).

Do these different definitions of SI have significant implications for policy and deliverable actions?

There is currently a debate whether agriculture and ecosystem services are best produced by "land sharing" or "land sparing". The essential difference is that "land sharing" produces agricultural and non-agricultural, ecosystem service outputs from the same area of land simultaneously, whereas "land sparing" allocates land use according to its comparative advantage.[2]

The definition used in the Royal Society report specifically states that SI systems should (i) raise farm production, (ii) not add to current levels of environmental degradation, and (iii) not involve converting any non-farmed land into farmland. This is clear support for the land sparing model. The Foresight report (2010) agrees with (i), suggests (ii) should reduce existing levels of negative environmental impacts and is silent on (iii). Further, it specifically supports reducing existing level of environmental impact by raising the productivity with which inputs are used (which is not the same as reducing the level of inputs currently used). Importantly, the Foresight report argues that land must "deliver multiple benefits simultaneously" (Foresight 2010: p11). Whilst the Royal Society report lends its support to land sparing, the Foresight report shifts attention towards land sharing.

These two influential descriptions of SI therefore suggest quite different and in some ways opposite approaches to increasing food and reducing adverse environmental impacts. The implications of the different definitions of SI on land use can be demonstrated by the conceptual model presented in Elliott *et al.* (2013) (see also Firbank (2012)). The model uses a production possibility frontier (PPF). A PPF depicts the various combinations of two outputs that can be produced using a constant amount of all factors of production. Figure 1 shows a PPF with agricultural production on the y-axis and ecosystem services on the x-axis as the two outputs of land. It demonstrates the theoretical trade-off between these outputs. Notice that there are points on the PPF where agricultural production and ecosystem services are complementary, but that for the wider range of outputs they are competitive. Farms on the boundary of the PPF (e.g. farm G) are defined as the most efficient farms because they produce the maximum amount of any one product for any given level of the other product. These farms can simultaneously raise yields and ecosystem services only at relatively low levels of agricultural production (the complementary areas of the frontier). Therefore, the majority of farms on the boundary of the PPF

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[2] For an introduction to land sharing and land sparing see POSTNOTE 418 (House of Parliament 2012). For further discussion see Garnett and Godfray (2012) pages 15-17 and references therein.

can only develop a SI trajectory if the PPF shifts up and to the right, which can only happen by using new technologies (the dashed line in Figure 1).

APPROXIMATE POSITION OF FIGURE 1

In Figure 1, farm z produces both agricultural and eco-system services, and so is an example of land sharing. This is the approach supported by the UK's Environmental Stewardship Scheme (ESS) and as more than 70% of farmland is entered into ESS (and nearly all farmland is subject to cross-compliance management standards) this represents a normal situation for UK farms. Figure 1 also shows that farm z lies inside the PPF. As it is not on the boundary of the frontier it has scope to raise input use efficiency using existing technology (either to increase agricultural production or ecosystem services, or both). Using the Royal Society report's (land sparing favouring) definition, farm z will exhibit SI if it changes its farming system to increase yields without reducing ecosystem service provision, such as shown by trajectory "a" in Figure 1, or if it increases yield and ecosystem services simultaneously (e.g. trajectory "b" or "c").[3] Note however that trajectory "d" represents an improvement in ecosystem services without an accompanying increase in yield and therefore does not represent SI.[4] The Foresight's definition would also not accept trajectory "d" as representing SI (for the same reason) but it would not accept trajectory "a" either because this does not reduce existing negative environmental impacts – it merely does not increase them.

There is another implication of the Royal Society report's refusal to allow non-agricultural land to be converted for agricultural production. The Foresight report would allow farm z to move in direction "f" by converting non-agricultural land into farm production if another farm agreed (in a legally binding and enforceable contract) to move along an off-setting trajectory, for example trajectory "e". Both changes must occur concurrently and the net impact must be an overall increase in agricultural

[3] Elliott *et al.* (2013) provides case study evidence showing how some farms in Great Briton have practiced SI (p xi), however they also note that "a number of farms which increased [crop] production also saw an adverse impact on environmental quality" (p xii).

[4] However, the report does acknowledge that this would "represent an improvement over the *status quo ante*" (Elliott *et al.* 2013: p vi).

production and an increase in ecosystem service production. It is this principle which underpins “biodiversity offsetting” (of which more below). Note also that although the definition of SI used in the Royal Society report means that the vast majority of farms on the PPF are not be able to develop a SI trajectory, by supporting off-setting agreements, through biodiversity off-setting the Foresight report enables such farms to contribute to SI.

There are two weaknesses in this conceptual model. To draws a PPF you need to know (i) how to calculate an index that weights as a single value the different ecosystem services that land can generate and (ii) what the trade-off between agricultural and ecosystem service provision is. Neither of these is known in practice. Whilst changes to farm production can be calculated, using for example total value based on market prices or net calories produced, there is no generally-agreed trade-off between different ecosystem services so it is not possible to calculate “an aggregate index of total non-agricultural ecosystem services” (the x-axis). In addition, any trade-offs that do occur will vary with location. Therefore Figure 1 assumes away a substantial element of the practical problems encountered developing policies to support farms to develop SI trajectories.

SI and innovative policy

Does producing more from less represent a new approach or “business as usual”? Aspects of SI sound suspiciously like the well-rehearsed and often directed demand that farming raises its efficiency within existing market, production and land use constraints. For example, the Curry Report (Policy Commission on the Future of Farming and Food 2002) advised farmers to improve production and economic efficiency as one of a three pronged approach to improving business profitability (the other two prongs being adding value and diversification). It advised that “Farming and food businesses, like any others, have got to be efficient” and refers to the need for growth in Total Factor Productivity (TFP). TFP is a measure of the increase in output per unit of all inputs. It is a measure favoured by the Foresight Report (2011); “Growth in Total Factor Productivity is important to the concept of sustainable intensification” (p 68) because “it will ease constraints on land, labour and other resources: 1% growth in TFP means 1% fewer resources are needed to produce the same amount of output" (p 68). However, a 1% growth in TFP may also be achieved with an increase in the total amounts of inputs used.[5]

Whether farmers and land managers will recognise and understand the technical difficulties of calculating TFP is uncertain, but they will most certainly understand the straightforward concept of improved efficiency as getting the same outputs from fewer inputs, or more outputs from the same inputs. It is after all what they have been doing for many years according to national statistics data published by Defra (2012b). The TFP of the UK agricultural industry is estimated to have increased by 25% between 1986 and 2011. This has been achieved more through lowering the volume of inputs (by 18%) than by raising volume of output (by 1.8%) over this period. Clearly UK farming has become much more efficient at converting inputs into outputs.

Unfortunately whilst TFP measures agricultural outputs, such as wheat and potatoes, the calculation excludes measurements of any positive or negative changes in environmental stocks and flows. Barnes (2002) draws attention to this with his calculation of "social total factor productivity": "When compared against growing public unease over the environmental effects of pursuing agricultural productivity growth, TFP indices become a misleading measure of growth" (Barnes 2002: p65). Indeed, Lawton *et al.* (2010) points to agricultural intensification of land use (which they state has been driven in recent years by agricultural policy) as the cause of the loss and damage of many high value wildlife sites and of the fragmentation and isolation of surviving areas of semi-natural habitats (the development trajectory "f" in Figure 1).[6] These albeit unintended consequences of modern farming together with the intensification of land use for marketable products is, the report argues, principally responsible for major declines (>80%) in farmland birds since the 1960s (p 9) and loss of crucial ecosystem services (e.g. carbon and water storage), and negative impacts on others (e.g. water quality) (p 7). This is a view supported in the UK by the

[5] TFP growth will occur is the proportionate increase in outputs is larger than the proportionate increase in inputs.

[6] There appears to be a contradiction here between the National Statistics which suggest the total volume of inputs has fallen by 18% between 1986 and 2011 and Lawton *et al.* (2010) statement regarding the increase in intensification of land use. This may however, be caused by a geographic redistribution of input use.

State of Nature Report (RSPB et al. 2013). So though growth in TFP can be based on the increase in the efficiency of input use, this cannot be used to measure SI nor is it evidence of SI.

The role of agri-environmental schemes (AES) in increasing production and environmental service provision

UK agri-environmental schemes (AES) allow farmers to simultaneously produce agricultural production and non-agricultural ecosystem services. The flagship AES is the Environmental Stewardship Scheme (ESS) which is largely the product of the Curry report's (Policy Commission on the Future of Farming and Food 2002) strong advocacy of the benefits of a whole-farm based, broad and shallow entry level stewardship (ELS) designed to pay "mangers for environmental management over and above their legal obligations" (p 81-84). The initial aim for entry-level tier was to "get more land managers involved with environmental protection and deliver benefits at landscape level" (Policy Commission on the Future of Farming and Food 2002: p67). To this end the report recommended that the new entry level tier should be kept "as simple and easy to administer for farmer and Government as possible" (p 84), which is one reason why over 70% of agricultural land in England is in ESS.

However, experience of AES within the UK supports Kassam *et al.* (2011) warning about the complexities of learning how to successfully implement AES alongside commercial farm production. AES, and particularly the (now) three entry-level stewardships,[7] have been criticised for failing to raise environmental standards above the reference level demanded by legislation. Their record in delivering environmental outputs has been criticised as "mixed" (Whittingham 2007: p7) and of so far having "delivered only moderate biodiversity gains" (Whittingham 2011:p 509). **[8]** Although Boatman *et al.* (2008) suggest there is "good evidence that UK agri-environment

[7] The Entry Level Stewardship (ELS), the Organic Entry Level Stewardship (OELS) and the Upland Entry Level Stewardship (UELS).

[8] AES have several objectives besides safeguarding and protecting biodiversity. These include the protection of the historic environment, promotion of public access and understanding of the countryside, protection of natural resources, prevention of soil erosion and water pollution and support for environmental management of uplands areas.

schemes have delivered significant benefits to biodiversity particularly for plants and birds of arable, species-rich grasslands, hedgerows, moorland and lowland heath, and some types of wetland" (para. 45: p 8), they are less positive of the role of AES in resource protection, which has "only recently become an explicit objective of some UK agri-environment schemes" (para. 41: p 7).

The Royal Society report recognises these criticisms. It rejects the widespread use of low-intensity AES on the basis of their "limited success" (p 46) to recommend "greater targeting with more intensive agri-environment schemes, often involving habitat restoration, in areas of particular importance to *society*." (p 46; italics added) – again showing their support for land sparing. Those areas "particularly important" to society should prioritise land use for "flood protection, carbon sequestration, critical biodiversity or *enhancing the health and quality of life of local people*, linked inevitably with greater intensification in other areas" (p 46; italics added). This gives insights into two critical impacts of SI on land management: SI will (i) involve land use planning to target land use, to (ii) in select places, deliver greater "social" at the expense of "private" value.

Additional insights into the future use of planning are contained in "*Land use Futures: making the most of land in the 21st century*" (Foresight 2010). This argues that there is "a strong case to develop a much more strategic approach (to land use)". It suggests that a strategic approach (taken to be a fifty year planning horizon) should be used to "guide incremental land use change, incentivise sustainable behaviours and to unlock value from land" (p 9). It does not specifically state that the value that needs to be unlocked is the social value, but this statement reflects the Foresight (2010) report's view of the key problem; the potential conflict in land use such that "more land for one use can mean less for another" (p 5). This insight is hardly new or news to farmers and farm mangers and planners whose farm enterprise and business management and strategic planning frameworks respectively have always involved juggling the various demands on land. The 2010 Foresight report's solution to delivering multifunctional land use involves integrating "the different and hitherto fragmented policy arenas and funding mechanisms." (p 35) accompanied by "*new* collaborations among *interested and influential stakeholders*, and recognition of the diversity of the motivations of land owners and managers" (p 35; italics added).

Integrating fragmented policy arenas is a key Coalition government financial management policy from which agriculture cannot expect to be entirely immune. Farmers are also accustomed to being told they must cooperate more, for example, the Curry report states: "The best way for a small farm business to get the benefits of being a large farm business is to collaborate with others" (Policy Commission on the Future of Farming and Food 2002:p 34). But in this context it is not clear whether *new* implies more of the same or innovative forms of cooperation.

"The Natural Choice: securing the value of nature"

For guidance to this and other issues it is advisable to turn to the recent White Paper on Nature (HM Government 2011) because a role of White Papers is to help stakeholders understand the basic issues involved. What does *The Natural Choice: securing the value of nature* have to say about: (i) how multi-functional land use is to be delivered, (ii) the trade-offs available in the way land is used, (iii) how the conflict between delivering social and private value from land should be addressed, (iv) whether innovative forms of collaboration are planned, and (v) the possible roles targeting and strategic planning might play in future land use.

The first point to note is that the White Paper does not use the expression SI, though it clearly embraces the concept. Its message is that multiple benefits are needed from land and these must be delivered in sustainable ways. It asks for increases in efficiency, reiterating the often advanced advice that the best way to improve sector efficiency is to raise the performance levels of the poorest, but interestingly it uses this argument in respect of raising the production efficiency of environmental as well as agricultural goods: there would be "major improvements in environmental outcomes if more land mangers raised their performance to the level of the best" (p 23). It supports an innovative approach to delivering multiple benefits through "integrated action at a 'landscape scale'" (p 18)[9] - which would represent a new form of collaboration for many (but not all) farmers (see Franks and Emery (2013) for examples of exiting landscape-scale agri-environment management within ESS, and

[9] See the Curry Report (Policy Commission on the Future of Farming and Food 2002) "There remains significant scope to increase the productivity of the farming industry, in particular by improving the efficiency of the worst producers" (p 26).

there are regional collaborative farmer-farmer agreements, for example ECOnet in Cheshire and the Devon Wildlife Trust's Culm Grassland project).[10] The White Paper is more supportive of ESS than the Royal Society report. Nevertheless, it recognises that the ESS does need revision if it is to "maximise its contribution" towards "our [i.e. the government's] over-arching objective to promote multiple benefits from ecological restoration at a landscape-scale, including through Nature Improvement Areas" (p 21). Government will see to it that Entry Level Stewardship (ELS) is revised to "yield greater environmental benefits, with better targeted agreements" and to increase its focus on outcomes (p 25).[11] Targeting of land use will also be used to help identify "where land can be managed to deliver multiple benefits, including improving water quality, flood alleviation and biodiversity" (p 29). Clearly the White Paper envisages a key role for ESS in delivering SI through land sharing and land sparing roles.

One innovation related to targeting introduced in the White Paper, and mentioned above, Nature Improvement Areas (NIAs) has now been introduced in 12 areas in the UK (DEFRA 2013). NIAs are innovative mechanism for exploring how local assessments of opportunities can be used for "restoring and connecting nature on significant scales". In fulfilling its landscape-scale activities NIAs reflect the view that partners will need to pool resources and get the best possible value from them (p 21). One of their key roles will be to support the creation of ecological networks, work that will be helped by "the recent planning reforms" (p 21), and by the creation of maps which show how "landscape character areas, water catchment and local authority boundaries relate to each other" (p 21).

Clearly the NIAs are one mechanism by which the White Paper has supported Lawson *et al.'s* (2010) recommendation to create a more coherent ecological network. Another is its support for biodiversity offsetting which might have an important role in this process. Biodiversity offsetting, a conservation activity "designed to deliver biodiversity benefits in compensation for losses in a measurable way" (p 22), is a

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[10] The catchment based, landscape scale approach is widely used to improve water quality. Farmers in these areas will therefore have experienced some form of coordinated action (see Southern *et al.* 2011).

[11] It should be remembered that the ESS already includes elements of targeting and payment by outcomes in its Higher Level Stewardship (HLS).

form of land sparing which could be used to "complement existing habitat designations that are designed to protect our most valuable biodiversity" (p 22).

The White Paper (HM Government 2011) also suggested establishing Local Nature Partnerships (LNPs) to work at a strategic scale to "strengthen local action". LNPs "will enable local leadership and may operate across administrative boundaries" (p 3) and will help to "deliver the multiple benefits we receive from good management of the land" (p 19). LNP "may comprise people from local authorities, businesses, statutory authorities, civil society organisations, land managers and local environmental record centres, as well as people from communities themselves." (p 19) – thus LNPs will represent the views of a wide range of stakeholders. By October 2012 48 LNP had been established.[12]

The focus of the Royal Society and Foresight reports is directed towards raising agricultural production without further damaging or whilst actively improving environmental quality respectively. However, the White Paper appears to switch these priorities, it appears to be focused more on raising environmental outputs without lowering production (an approach which would include trajectory "d" in Figure 1 - which neither the Royal Society or the Foresight reports would allow – but exclude trajectory "a"). Although either focus can deliver SI, the difference in emphasis has implications for the distribution of costs and benefits between farmers, and between farmers and society. The first, with its emphasis on raising agricultural production, is more likely to benefit farmers as they seek to maximise the private value of their land, the second approach, raising ecosystem services, favours unlocking social value.

Financing SI: payment for environmental services (PES)

With the total CAP budget constrained, raised compensation payments for loss of farmers' property rights can only be financed by redirecting payments from existing CAP budgets (for example from the Pillar I Single Payment Scheme (SPS) payment). As this would result in no "new money" it cannot deliver any net financial transfers to the sector. However, new sources of money may be forthcoming through the

[12] For more information on LNPs see (DEFRA 2012a).

voluntary use of biodiversity off-setting, and from the beneficiaries of the improved environmental outcomes. The UK's South West Water's £9m, 5 year, six project "Upstream Thinking" programme is an example of a beneficiary financing improvements in water quality and in so doing reducing their water treatment costs. This programme is an example of payment for environmental services (PES) approach to financing eco-system service provision.[13]

An example of the property rights involved and the ecosystem services, beneficiary pays, agenda can be given by considering the possible instruments that could be used to convert farmland into flood protection areas, an example of land sparing. Table 1 shows a range of existing land-related policy instruments that might be used to secure such land use change. The potential disruption to the farming system and extent of financial losses incurred during flooding suggest compensation payment should be made. Therefore declaring the flood plain land a Flood Protection Zone "FPZ" with a similar land designation as a NVZ would not be appropriate as farmers in NVZ do not receive compensation for the limits placed on their use of nitrogen fertilizer (and other constraints). As some mechanism will be needed to ensure 100% participation by land users/owners, as a rise in water level on one field will affect all the land on the flood plain, the most appropriate instrument is either extending the power of the majority over a minority of non-collaborators (similar to the powers conferred to the majority of commoners in the Commons Act (2008)), or to give the land the status of an SSSI with a compulsory management agreement.

However, this change in land use appears ideally suited to the beneficiary pays, ecological services, agenda because "one in five properties built in the floodplain [over the last ten years] were in areas of significant flood risk" (Adaptation sub-Committee Progres Report 2012:p 8), and because insured losses from flooding and

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[13] 'Payment for environmental services' (PES) "has emerged as a policy solution for realigning private and social benefits resulting from decisions related to the environment. PES is based on external environmental service beneficiaries making direct, contractual and conditional payments, to land managers in return for adopting practices that secure ecosystem conservation and restoration," (Rollett *et al.* 2008:p 32).

other severe weather events cost around £1.5 billion/year (p 8).[14] In such a case each benefiting insurance company would be expected to pay its share of the total compensation costs. Income forgone might form the basis of these payments, but one-off capital payments to improve buildings and fences may also be needed to ensure animal welfare.

Although financial compensation could be paid through changes to existing AESs, there might be advantages to farmers if the beneficiaries of deliberately allowing land to be flooded (i.e. the insurance companies) financed the compensation payments. When a beneficiary compensates farmers the value of the payment is not constrained by current European Commission AES compensation regulations. These regulations place an upper limit on payments which are based ("somewhat perversely" according to the Ecosystem Markets Task Force (2013:p 23) on the farmer's income foregone, any direct costs incurred and their transaction costs. This does not allow changes in farm management to be valued at either the estimated real value of the ecosystem services provided or the insurance companies' opportunity cost. An additional potential benefit of beneficiary pays is that the length of the agreement can be longer than that offered under AES (see the Vittel water example in (Rollett *et al.* 2008:p 48-49, Box 10)). Whilst there are therefore benefits to farming to accept PES as representative of the value of the non-agricultural ecosystem services in Figure 1, putting PES into practice where there is more than one beneficiary from a change in land use may be complicated by the free-rider problem. However, given current and future pressure on budgets PES, and the benefits likely to flow to the farming community of switching from their opportunity costs to those of the beneficiaries, PES is likely to play an increasing role in incentivising future ecosystem service provision across the UK.

APPROXIMATE POSITION OF TABLE 1

[14] The Adaptation Sub-Committee (2012) stated that "Managing water at the catchment scale to attenuate flood flows also plays an important role in adaptation to flood risk" (p 11), but it has put of further examination of this point until its next progress report.

Boundary Organisation Theory (BOT): an approach to preserving the flexible interpretation of SI

Despite different interpretations of SI, with the Royal Society report appearing to favour land sparing and the Foresight reports appearing to favour land sharing, there are many overlaps in terms of possible farm development trajectories and proposed policy responses need to include elements of both (Garnett *et al.* 2013). For example, ecological networks can be created by incorporating elements of land sharing and land sparing, and the White Paper clearly includes elements of both with its support for biodiversity offsetting and development of ESS. It also opens up decision making to innovative governance organisations (LNPs) and increases targeting (NIAs).

This pragmatic approach reflects Pretty's (1997), one of the first to use the term SI, vision of SI as one which relies on the "integrated use of a wide range of technologies to manage pests, nutrients, soil and water" (p 247) involving and using local people and knowledge within an adaptive framework. He eschewed the use of "comprehensive packages of externally-supplied technologies" (p 147) to stress that SI "must not prescribe specific, concretely defined technologies or practices" because this "would restrict future farmer options" (p 247). Rather SI should "create the enabling conditions for locally-generated and adapted technologies" (p 254). This view is based on the clear understanding that the solution to these complex problems requires detailed site-specific information. Given that any solution will need to address the set of resources and constraints found at each location, there is no reason for SI to be limited to either the land-sharing or the land-sparing approach. As the White Paper suggests, both approaches need to be available for consideration to allow whatever approach is agreed to address these site-specific resources and constraints.

It is argued here than Boundary Organisational Theory (BOT) can provide insights into resolving site-specific problems that are long-standing and complex and which involve a large number of diverse stakeholders (Guston 1999 ; Star and Griesemer 1989 ; Franks 2010). BOT argues that a concept that is loosely defined can become a "boundary object" and thus remain open to a wide range of interpretations. By deliberately blurring the boundaries between two or more distinct social worlds a boundary object allows stakeholders from all sides of the boundary to present their point of view in ways most favourable to their own perspectives and constituencies

(Guston 1999). BOT argues that this malleability allows boundary objects to be reconfigured from different perspectives and viewpoints and that this allows them to evolve through discussion and debate to better reflect new values and evidence and thus lead to more productive and inclusive policy making (Guston 2001). The resulting re-formulised agreed package of action (which is termed in BOT a "standardised package") is designed to allow changes to practices on all sides of the boundary so that work can be done and progress made (Guston 1999).

Sustainability is an example of a concept that has been allowed to become a boundary object. Agreeing a single definition of sustainability has proven "extremely problematic" (Rigby and Cáceres 2001), however the term continues to be widely used by a large number of stakeholders. Indeed, it is the lack of agreement over its precise definition that has allowed academic from many disciplines to contribute to its study, and to the related study of sustainable agriculture (SA).[15] What is important is that a boundary object needs to be a concept or idea that is "understood" by everybody; "I know it when I see it" was White's comment about sustainability (White 2013)). This is sufficient, as it allows the term to be widely interpreted and therefore widely used but critically it also means that it carries little prescriptive baggage with respect to operational practices. This is precisely the use Pretty (1997) supported when he used the expression SI. By allowing SI to retain a fuzzy definition stakeholders will be able to engage in negotiations around the boundaries of the problem (Cash 2001:p 450) whilst remaining fully engaged with the deliberations which helps avoid prescriptive interventions which may disregard site-specific features, characteristics, evidence and perspectives. Clearly SI is best viewed as another example of a boundary object.

Disadvantages of allowing key policy concepts to have a flexible definition

No single phrase or concept can be expected to encapsulate within it all the diverse policy options and practices that might be needed to resolve a problem. As a

[15] It is doubtful that the Royal Society's Working Party fully understood the link between SI and boundary objects and BOT. Its report states that any definition of SI requires a "clear definition of agricultural sustainability" (Baulcombe *et al.* 2009:p 7), even though no definition of sustainability has been widely accepted the concept itself has been (Rigby *et al.* 2001).

“boundary object” such practical difficulties are understood and accepted which helps SI to act as a focus around which negotiations can begin and develop. This would help avoid it being so tightly defined as to prevent discussions adopting whatever practical policies and actions best address each individual site-specific set of problems. There are, however potential difficulties associated with allowing definitions of key policy concepts to remain flexible. These problems relate to (i) the practical use of the term, (ii) the assessment of the success of projects that claim to have delivered SI, and (iii) the apparent invitation a blurred definition has for organisations and academics to use scarce resources to devise their own definition which often tries to incorporate individual’s/organisation’s preferred approaches, perspectives and policy instruments. Each of these difficulties is considered in turn.

Before being able to apply the concept of SI to Scottish agriculture, Barnes and Poole (2012) argued that it was “important if we are to identify the potential for sustainable intensification to be clear on how it is defined” (p 2). This is because they needed to select indicators which contained information that could be used to assess whether Scottish agriculture has been developing along a SI trajectory. A lack of any widely agreed operational method or measures of success are also not immediately helpful to businesses which may be required to alter practices to prove, by audited measurements, that they have delivered SI in practice. This may be especially important should they wish to market their produce as the output of a SI production system. However, as with the analysis of sustainability, the indicators selected for measuring SI are very likely to be limited by the available data (Rigby *et al.* 2001), and therefore whatever theoretical definition is proposed, analytical sections of papers often involve pragmatic compromises, at times to the extent that the theoretical discussion become irrelevant in the practical analyses/applications.

Flexible definitions can lead to unclear policy goals and ill defined targets making assessment of project success difficult. This is a charge levied against many agri-environmental schemes (AES), for which a lack of specific goals meant that “in the majority of studies, the research design was inadequate to address reliably the effectiveness of the [AE] schemes” (Kleijn and Sutherland 2003:p 947). Potentially this allows organisations to claim to have developed along any particular trajectory by selecting only favourable indicators from the wide range of available metrics.

However, any *ex-post* determined measurements are likely to fall into this trap, and it is best practice to agree how projects are to be monitored at the same time as the action plan is finalised to allow both to address pertinent site-specific issues.

An additional disadvantage of a flexible definition is that it offers an open invitation to academics and organisations to devise their own more specific, all encompassing definition. This was the fate for example of "sustainability" and it has already started for SI - the demand that SI be redefined into a more exact and precise concept, which was raised by Barnes and Poole (2012), appears to be widespread. For example, in written evidence to the House of Commons Environmental Audit Committee (HoCEAC 2012), the Campaign to Protect Rural England state; "The government should more clearly define what it meant by the terms "sustainable intensification"" (p 54). Smith's (2013) definition of SI combines intensification - delivering more from less - with the Bruntland Commission's definition of sustainability to arrive at; "The process of delivering more safe, nutritious food per unit of input resource, whilst allowing the current generation to meet its needs without compromising the ability of future generations to meet their own needs" (p 19). The USDA's (2011) Feed the Future programme's definition goes even further away from the Royal Society and the Foresight reports definitions to describe SI as a concept in which; "research (such as technologies and best management practices) and non-research inputs (such as fertilizer, quality seed, water, energy, market information, and others) come together with improved access to markets to increase productivity, enhance environmental sustainability, reduce risk, and encourage producers to increase investments to agricultural production." (p 20). The outcome of demands for a more specific definition of SI has therefore resulted in substantial changes in emphasis from the definitions proposed by the Royal Society and the Foresight report.

In the same volume of written evidence, the World Society for the Protection of Animals (UK Office) criticises the Foresight report for using SI without distinguish between "Intensification "at the bottom end of the scale", which may be beneficial: for example improved management of cattle browsing on poor-quality vegetation in developing countries; and intensification "at the top end of the scale", which is harmful in both developing and developed countries (HoCEAC 2012:p 20). This demonstrates a lack of appreciation of SI as a concept best understood through the lens of BOT which argues that SI needs to retain a flexible definition precisely to address such diverse situations, because it is this flexibility that allows these different circumstances to be addressed using site-specific policies based on pertinent evidence derived from all possible sources.

Perhaps the key lesson for academics is that where site-specific problems require site-specific solutions focusing on delivering the demanding research agenda, which has been identified for SI (and which is considered further below), would provide a more constructive use of academics' time than devising yet another definition of a concept that is already well enough described to be widely understandable.

Implications for research agendas

How are farmers and land mangers to deliver TFP growth whilst raising the environmental quality or at least without causing any additional deterioration in environmental quality? Despite advocating the need for SI, the Royal Society report states that there are "few easy answers to the question of how to increase yields sustainably" (p 46). The report recognises the difficulties as the "trade-offs between economic gain from increased production and external impacts" (p 46) and that; "potential adverse impacts on the environment include those on biodiversity and the provision of ecosystem services" (p 39). It concludes that "SI of agriculture requires a new understanding of these impacts so that interventions can be targeted to minimise adverse effects on the environment", (p 39), which in terms of the Elliott *et al.* (2013) model would (i) move the PPF outwards (as shown by the dashed line in Figure 1), and (ii) allow farms to develop along trajectory "a".

The Royal Society report states that "no techniques or technology should be left out before risks and benefits are assessed" (p 8), and recommends that the industry continues to use biological scientific-based technologies and to develop synergies between genetic and agro-ecological approaches. It further suggests that the use of non-renewable inputs must decrease; that nitrogenous fertilizer is manufactured using renewable sources of energy and hydrogen; and denitrification in soils must be reduced. The Foresight report suggests that "Pursuit of the [SI] agenda requires a much better understanding of how different options for policy, both within and outside the food system, have impacted on biodiversity and ecosystem services" (Foresight 2011:p 144). The Commission of Sustainable Development(Beddington *et al.* 2012) presents a summary of the many key research areas that promise useful contributions to SI (p 29):

- the development of new varieties or breeds of crops, livestock and aquatic organisms;
- advances in nutrition for livestock and aquaculture using feed additives or formulated feeds to increase productivity gains and reduce methane emissions from ruminants;
- improved soil management that preserves ecosystem functions and sequesters carbon;
- agro-ecological approaches that complement the biological and ecosystem services that inherently support agriculture and that better manage risks; and
- the promotion of engineering technologies that improve water use efficiency.

Among the research questions these approaches need to address are: what is the trade-off between yield and ecosystem services, and within different ecosystem services?[16] How much land needs to be spared from and shared with production to support biodiversity and ecosystem services? What should the balance between land sparing and land sharing be? Where should these land uses be located? But such questions appear to involve strategic planning authorities as much as, if not more than, scientists because even when technologies have been developed agreements need to be reached to use them, and farmers in the past have been reluctant to give up their right to use their land as they see fit. In addition the sum of all the agricultural and ecosystem provisions agreed through local negotiations need to deliver national strategic specific and absolute requirements – which can only be achieved using a strategic plan coordinated at the national level.

[16] Ripoll-Bosch *et al.* (2012) shows how difficult this is. Their work demonstrates the generally negative correlation between economic and environmental indicators "the higher the economic sustainability, the lower the environmental sustainability" (p 46). However, see Firbank *et al.* (2013) for evidence that farms can develop a SI trajectory.

Discussion

Is SI an "oxymoron" as Marsden (2010) suggests or is it, as the FAO's (2011) publication "Save and Grow" suggests, a "new paradigm of agriculture" (p 1)? Clearly it is possible for land to be farmed more sustainably and intensely using either the land sharing or the land sparing model respectively. Whether it will be is likely to be determined by how SI is translated into practical action; will it reflect business-as-usual as Smith (2013) suggests,[17] captured by corporations and dominated by packages of high-tech solutions, or will it provide an underpinning to Pretty's (1997) concept that rejects one-size-fits-all solutions and the use of pre-specified technological packages to arrive at site-specific solutions?

It has been argued above that the flexibility with which SI is currently described should be considered beneficial, in part by helping prevent a one-size-fits-all policy response, rather than been seen as a problem because of possible adverse affect on the "way in which a concept is understood" and on "the policy implications that may be inferred" (HoCEAC 2012). It is not realistic to expect definitions to capture the full range of potential policy responses that might be used to resolve a wide range of diverse and often long-standing and complex problems. The World Society for the Protection of Animal's evidence referred to above argues that a clearer definition of SI would allow different policy responses towards intensification at the "bottom end" and at the "top end" of the scale. But this is unlikely to be the case as more precise definitions are likely to increase the constraints placed on possible responses. Pretty's desired outcome was that SI would be used to help ensure that actions taken would be relevant to the problems faced and not constrained by definitions (Pretty 1997). In his investigation of Scottish agriculture, Thomson (2011) shows how too little intensification has harmed the provision of ecosystem services in some highland areas, whilst in other areas he is able to argue that too much intensification has created uniform and homogenous landscapes. The policy response needs to be different in each case, and a flexible definition allows for this to happen. BOT explains the value of deliberately blurring the meaning of policy concepts because it helps create an

[17] Smith (2013) believes that SI can be regarded as an "enhancement of current "business as usual", in which agricultural systems remain largely unchanged, and demand follows current projections, but in which agricultural production becomes more efficient" (p 18).

inclusive approach to solving long-standing problems through the bringing together of stakeholders to develop site-specific solutions rather than adopt prescriptive bundles of (often externally developed) technologies.

A potential limitation of SI is that it is limited to supply side adjustments, demand side changes are not within its scope (Godfray and Garnett 2014). The extent to which farming systems and consumption patterns will need to change will depend on the evolution of demand. Smith (2013) argues that "a reduction in livestock produce consumption could greatly reduce the need for SI through reduced demand" (p 21). FAO estimates global per person kilocalorie production in 2010 at 5,359 kcal (FAO 2012:part 3, p 174). As the average man requires about 2,500 kcal and the average woman about 2,100 kcals, global production is therefore some 2,000 kcal/person more than is needed to feed our current population. More equitable distribution of the food that is produced would clearly reduce the need for such a large increase in food production by 2050 and therefore influence the balance between the sustainability and intensification.

Tomlinson (2013) reviews the estimates of the increase in food production needed of between 70 and 100% of today's level to feed 9 billion people by 2050, and concludes that it has been incorrectly derived. One consequence of the wide-spread use of the 70/100% estimate (which she terms the "wrong statistic" (p 88)) has been to allow dominate institutions and individuals to frame the food security problem as one that needs to be solved by technological development rather than to challenge the overall trajectory of the food system (p 86), despite the likely adverse consequences to greenhouse gas emission and human health should demand for food in 2050 mirror the current dietary preferences for livestock products. As a result alternative approaches based on agro-ecology and "food sovereignty", such as that advocated by The International Assessment of Agricultural Knowledge Science and Technology for Development (IAASTD) have, she argues, had little impact on the global food security discourse[18] Even though agro-ecosystem approaches have been identified as

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[18] The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) was a three-year international collaborative effort (2005-2007) initiated by the World Bank that assessed agricultural knowledge, science, and

suitable for raising intensification particularly "at the bottom end of the scale", for example Kassam *et al's* (2011) believe SI in practice will often need to incorporate the main elements of CA which are listed in Table 2. It is sensible that global food security should focus on demand-side changes when sufficient calories are currently produced globally to feed 9 billion people if they were redistributed accordingly. It is difficult to argue with Smith that "the scale of the problem means that we are not in a position to choose between SI or a fundamental systemic change in food production system, we clearly need both" (p 22).

APPROXIMATE POSITION OF TABLE 2

Although itself not without problems, it is an easier task to measure "intensification" than it is to measure "sustainability". Intensification is traditionally measured by the quantity of inputs used per area of land, but Russell argues that in this context intensification needs to include increases in yield derived from the use of innovative inputs, such as genetically modified seeds (HoCEAC 2012)[19]. There are a range of measurements that might be used (Barnes and Poole 2012 ; Thomson 2011). These tend to be farm system related and are well understood by farmers, advisors and academics. However, as the research agenda shows, we know a good deal less about the trade-offs between ecosystem services in different area or how to manage those trade-offs. There are also spatial and temporal issues involved: intensification occurs by deliberate decisions and actions on specific locations and can be recorded over short time scales, whereas sustainability might affect larger areas (landscapes rather than individual farms) and may take much longer to have a measurable impact. These measurement issues may result in a disproportionate share of funding being allocated to support raising intensification rather than sustainability, resulting in a preferential use of biotechnological solutions at the expense of agro-ecological approaches, with the danger that the SI research agenda is "captured" by agri-business corporations

technology (AKST) with respect to meeting development and sustainability goals of reducing hunger and poverty, improving nutrition, health and rural livelihoods, and facilitating social and environmental sustainability.

[19] Including knowledge-intensive inputs as part of "intensification" is also supported by the Royal Society report.

(Friends of the Earth 2012). This raises the likelihood that SI becomes no more than an extension of “business-as-usual”.

The White Paper recommends a mixture of policy responses drawing on both the land sharing and land sparing models. It favours moving some ESS payments from the public to the private sector as suggested by the PES agenda. Whilst this may have practical advantages for land managers, it can be difficult to identify who the beneficiaries are and which farmers need to change their farming practices. In addition, making payments for the provision of a particular environmental service from an area of land may reduce the supply of other environmental services which are valued by consumers of the countryside who are not compensated for their loss. It will be necessary to coordinate local agreement about which ecosystem services to prioritise rather than adopting the pragmatic approach of privatising those ecosystem services which are most easily privatised. Doing this will require national level, strategic planning, and this is acknowledged in the White Paper where “a strategic approach to planning for nature within and across local areas” is advocated (HM Government 2011:p 3).

The real innovation within the SI agenda is the argument that land should be used to enhance its social at the expense of its private value where this is appropriate. This is another example of the need for an over-arching planning authority with perhaps new legislative powers. For example, developing flood plain designation areas and providing cleaner water from land needs landscape-scale coordination, whilst delivery of nationally agreed carbon sequestration targets will require landscape-scale agreements overseen by national coordination.

What form this over-arching strategic authority will take and how will it deliver local site-specific agreements whilst ensuring that the multiple outcomes from land satisfy national needs, are social rather than scientific questions.[20] This conclusion was reaching by Firbank (2005) in his paper “*Striking a new balance between agricultural production and biodiversity”*. Though he does not use the expression SI his

[20] This is a key characteristic of a category of problems that have been described as “wicked”; these are problems that cannot be solved by science alone but need to be resolved - often time and time again - by agreements between people (Franks 2010).

discussion of the challenges balancing agricultural production against biodiversity management within the context of sustainable agricultural development emphasises the social as opposed to the scientific challenges. He concludes that "there can be no theoretical "optimum" balance between production and biodiversity, as environmental goals depend greatly upon decisions about scales (from local to global, immediate to long) and the viewpoints of stakeholders" (p 163), and continues; "indeed, the social challenge of delivering sustainable agricultural landscapes is far greater than the scientific one of researching what they might be like" (p 163). Putting SI into practice faces the same challenge.

Conclusions

If SI represents a new paradigm within environmental policy it is because it eschews prescriptive approaches and focuses on using site specific solutions to deliver social value from privately owned land where appropriate. SI led policies will be better able to deliver multi-functional land use if they include elements of land sharing – such as agri-environment schemes, alongside elements of land sparing – such as biodiversity offsetting and improved land use targeting. To help implement such key changes at the local level, government has established collaborations involving entirely new forms of governance; LNP working across NIA and elsewhere. But government recognises that these organisations and the agreements they foster will need to comply with a national strategic planning framework. Whilst the SI research agenda focuses on science and the tradeoffs between agricultural and ecosystem services, the key difficulty facing SI is how to manage and balance the trade-offs between the rights and needs of private land owners and the rights and needs of society. As this is about who controls the use of land it raises as many social as scientific challenges.

Doubtless solutions to this social challenge will be assisted by scientific advances related to improving our understanding the trade-offs between agricultural production and ecosystem services, nevertheless the success or otherwise of SI should be judged on how the conflict about what land is for and how to release its social value is resolved. How will strategic imperatives match centralism to localism and how will rights to object affect what land users and owners are allowed to do with their land are key unanswered questions. The mechanism by which a national spatial strategic plan is introduced, and the way in which it operates, whether through voluntary consensus or compulsory dictate, will have to be addressed for SI to become a practical reality. As these are people based problems their solution can be helped by a wider understanding of BOT because of the framework it provides for bringing diverse interests together to jointly develop practical response drawn from the full range of tools and instruments available for the resolution of complex problems.

Figure 1. Conceptualisation of sustainable intensification trajectories of farms within a UK context) (Elliott et al. 2013:p vi). Farm G is on the PPF, farm z is inside this frontier. Adapted to include expansion of PPF due to innovative technologies.

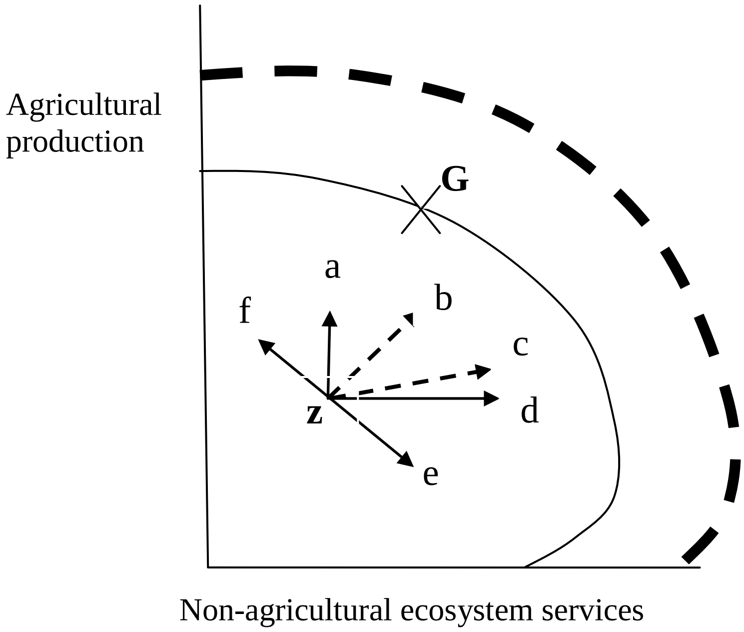

Table 1. Current policy instruments which could be used to manage farmland in a flood plain as part of a Flood Protection Zone (FPZ).

Geographical targeted	**Coverage**	**Compulsory (C)/ voluntary (V)**	**Payments**	**Example**
No	Everybody	C	No	National legislation (includes codes of practice)
No	Everybody	V (but linked to entitlement to receive Single Payment Scheme payment)	No	Good agricultural and environmental conditions (GAEC)
No	Individuals	V	No	Voluntary Pesticide Initiative
No	Individuals	V	Yes	AES- ESS-ELS
Yes	Individuals	V	Yes	AES-ESS HLS
Yes	Majority	V/C (for minority)	Yes	Commons Act (2008) : applies to farmer agreements over common land
Yes	Everybody	C	No	Nitrogen Vulnerable Zone (NVZ) SSSIs without management agreements
Yes	Everybody	C	Yes	SSSIs with management agreements

Table 2. Kassam et al. *(2011) SI production systems based on conservation agriculture (p 39)*

This involves integrating the three key principles of conservation agriculture:
• minimising soil disturbance be mechanical tillage,
• enhancing and maintaining organic matter cover on the soil surface and
• diversification of species
with four additional elements;
• the use of well adapted, high yielding varieties,
• enhanced crop nutrition (based on healthy soils),
• integrated management of pests, and
• diseases and weeds and efficient water management.
Kassam *et al.* (2011)caution that such a production system would be “knowledge-intensive and relatively complex to learn and implement” because farmers would need to be familiar with many possible combinations of practices and to select between them according to local production conditions and constraints (p 39).

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