THE SUSTAINABLE INTENSIFICATION OF EUROPEAN AGRICULTURE

A REVIEW SPONSORED BY THE RISE FOUNDATION

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With contributions from Professor Alois Heissenhuber
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Sustainable Intensification of European Agriculture

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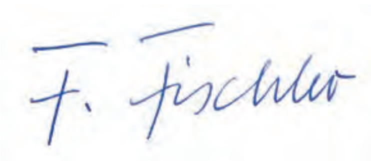
Preface

This report has been undertaken on the initiative of the Public Utility Foundation for Rural Investment Support for Europe (RISE).

At its creation in 2007, RISE launched a debate on the interconnected world challenges of food and environmental security, contributing to the annual Forum for the Future of Agriculture (FFA), which has become the key annual conference for farming and environment in Brussels. More recently, RISE has devoted particular attention to the sustainable intensification (SI) of agricultural production in a world in which the population is growing quickly and food availability is challenged by climate change and rapid urbanization, and also by a realization that intensive agriculture has been damaging biodiversity. This puts pressure on farmers to improve their productivity yet at the same time to significantly improve their environmental performance.

Aware that we are not alone in working on this critical subject, it was important to review our first findings with academics and practitioners and get their feedback. Therefore, a consultation process was launched through two workshops. The first workshop was held at the European Parliament in January where the initial findings were presented to a group of invited experts under the leadership of MEP Paolo De Castro, Chairman of the Agriculture and Rural Development Committee (COMAGRI). RISE had already contributed to a report on tools to produce public goods in agriculture that COMAGRI had launched in preparation for the deliberations on CAP Reform in 2011. In the spring of 2014, RISE held a second workshop at the FFA on indicators to assess how to measure farm environmental performance in order to manage it. This was followed by three FFA breakout sessions on SI, respectively on practical approaches and policy approaches in Europe, and perspectives from beyond Europe. This report builds on those debates. It deepens the reflections on SI undertaken by RISE, in particular as regards the meaning of SI, the actions to progress it, and the lessons that can be drawn from the report's three case studies. It reaches a number of conclusions as to the changes that are required in the CAP if it is to become more productive as well as more sustainable, suggesting issues that require further research.

The report has been led by Professor Allan Buckwell with contributions by Professors Winfried Blum and Alois Heissenhuber and their teams, who dealt in particular with the report's case studies on the land quality, nutrient management and biodiversity aspects of agricultural production. The study reflects a general consensus without implying total agreement on each sentence of the report. The same holds a fortiori for the expert advice received through the consultation process. Whilst the report clarifies the meaning and aims of SI and addresses the most relevant queries, it brings out new questions and avenues that need to be explored. RISE is planning to continue the vital research in this area and welcomes any offers of support and knowledge exchange.



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Executive summary

Context and purpose

The concept of sustainable intensification has come to the fore in recent years as a response to the challenges confronting ***global*** food security. These challenges are principally continuing population and economic growth in the face of scarcities of agricultural land and water and the dangers posed by climate change, agricultural pollution and biodiversity loss.

This project was initiated by the RISE Foundation to explore the relevance and meaning of the concept for the European Union and for its future agricultural policy. Two important features of the project have been consultations with experts, officials and practitioners at two workshops in Brussels, and three case studies utilizing on-going research into soils, nutrient recovery and biodiversity protection to explore specific dimensions of the concept. A clear consensus which emerged from these consultations and research is that sustainable intensification *is* a useful, globally based, concept which aims to steer farmers to land management which has a better balance between food production and the environment.

The prime logic behind the phrase is the assertion that it would be unacceptably damaging to climate and biodiversity if the necessary future expansion of global agricultural production were based on further conversion of forest, grasslands and wetlands. There has been large-scale destruction of these ecosystems over the last 150 years and much evidence to show the biodiversity loss, pollution, and climate impacts of this land use change.

This leads to the conclusion that further increments in global food output must come very largely from higher yields on existing agricultural land. This was the main route through which agricultural production expanded in the 20th Century. The difference in future must be a step reduction in the negative environmental impacts of agriculture. These are the arguments which lead ineluctably towards the concept of sustainable intensification of existing agricultural land. No assumptions are made in the report about targets for production growth globally or in Europe, however it is an underlying assumption that some production increase is required.

It is constantly asserted that tackling the issue of global food security must deal with policies and efforts to contain growth in food consumption, e.g. through reduced waste, as well as expanding supplies. There is no disagreement at all with this assertion yet this report confines itself to issues of agricultural production. The reasons are that sustainable intensification refers to production not consumption, and the expertise and interest of the organisations and researchers involved concerns agriculture. In addition, the demand side issues (food waste, food consumption and dietary patterns), and the policies to steer society towards more sustainable consumption involve subjects, policy instruments, approaches and institutions utterly different than those directed towards agricultural production and environmental land management by farmers which are the subject of this report.

What is sustainable intensification?

The definition suggested by this report is as follows. *Sustainable Intensification means simultaneously improving the productivity and environmental management of agricultural land*.

The phrase is used throughout this report in the sense of being an aspiration. Two general conclusions about sustainable intensification are:

- *Sustainable intensification does not point to a single development path for all agricultural systems or farms. The direction of the path and the actions required to meet it will depend partly on the conditions, particularly the current agricultural productivity and environmental performance of a farm or system.*
- *A sustainable intensification path could mean an increase in the output per hectare of environmental services of the farm or an increase in agricultural products per hectare, it does not only mean the latter.*

The application of the concept to the European Union

Five considerations led to the conclusion that the globally motivated concept of sustainable intensification when applied to the EU must place most emphasis on the first word of the couplet. The first is that most of the new pressure for additional food production will arise outside the EU. Added to this, EU agricultural production is already amongst the most intensive in the world, and the resulting steady productivity growth in Europe has meant that the area of EU agricultural land has slowly been falling. Agricultural encroachment onto new lands is not the problem in the EU; indeed the reverse process of agricultural abandonment is more often of concern for environmental and social reasons. The critical EU issue is that the past intensification of agriculture is associated with pervasive undesirable environmental impacts in Europe. An additional concern is that agricultural imports into the EU are associated with environmental damage in the exporting countries. Therefore it is argued that the role of European sustainable intensification is to show how high intensity, productive agriculture, can be combined with much higher standards of environmental performance. The emphasis has to be to find ways to continue the process of technical change in food production to radically improve the resource efficiency of European agriculture and in the process to meet European citizens' ambitions for high standards of biodiversity, climate, soil, water and cultural landscape protection. In short, in the EU interpretation of sustainable intensification must place most emphasis on improving sustainability.

Deconstructing sustainable intensification

The component words of this phrase and their combination are subject to a range of interpretations. The report therefore devotes much space in trying to clarify them. This partly amounts to destigmatising intensification and showing the wide range of interpretations of the word sustainable. In the context of agriculture, **intensity** is well defined as a ratio of inputs or output per hectare. It is relatively easily measured but it is generally denigrated! In contrast, **sustainability** is not well defined, or measured; yet it is universally supported!

When reference is made to "intensive agriculture" this invariably refers to a ratio of a restricted range of inputs per hectare of land especially fertilisers, pesticides, water and machinery for crop production and high density housing systems for animals. There are understandable reasons for focusing on these specific inputs particularly because if they are used inappropriately they contribute to pollution of water and atmosphere and destroy habitats and biodiversity.

The prime objective of sustainable intensification is not intensification *per se*, and certainly not an increase in intensity of use of environmentally harmful agricultural inputs. Rather the prime objective is to improve the resource efficiency of agriculture. A great deal of intensification can and must, in future, take the form of added knowledge which will affect how physical inputs are combined and managed. A suggested shorthand to describe what sustainable intensification means is ***more knowledge per hectare***! Similarly, increasing levels of knowledge are needed to manage the ecosystem services on which agriculture relies. Intensification of agriculture, especially in Europe is therefore not primarily about the use of more fertilisers, pesticides and machinery applied per hectare, but the development of much more knowledge intensive management of scarce resources to produce food outputs with minimal disturbance to the natural environment, and more environmental outputs too.

The environmental outputs of land management should be on an equal footing with the food and energy outputs. Unfortunately the word 'production' has been deeply embedded to refer only to planned outputs which are marketed and sold. A virtue of the relatively new language of ecosystems is that it seeks to place the provisioning services of nature, e.g. food and energy which are produced and sold through market-based processes, on the same basis as the supporting, regulating and cultural services, which are non-marketed. A correct interpretation of sustainable intensification should embrace examples where the production to be intensified per hectare can equally refer to the conservation outputs, e.g. pollinators or fledged lapwings per hectare, as to agricultural products.

Sustainability and sustainable development

The 1987 Brundtland Report defined sustainability as "*meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*"

Whilst there is universal agreement on the desirability of the concept, there are quite strongly held differences on how it is interpreted and what it means for policy and practical action. Some of these differences are philosophical or ideological and do not readily lend themselves to resolution by appeal to empirical evidence.

There is general agreement that sustainability must be considered under the three pillars: economic, environmental and social. Yet despite the lip service paid to three equally important pillars of sustainability, it is common to observe that analysis is often focused mostly on the environmental dimension. Disagreements about weak versus strong sustainability are not resolved. A recent summary of this debate suggested that weak sustainability is associated with growth optimists who see natural capital as a production factor and a source for human welfare. Whereas strong sustainability supporters stress limits to economic growth and see natural capital as a basis for human survival (Kaphengst (2014). This issue is closely related to the debate on whether sustainability implies the existence of limits, thresholds or tipping points beyond which a system cannot recover, going into irreversible decline. There are strong beliefs that some such limits exist, and that the effects of human activity have taken us, or are about to take us, beyond these thresholds. However outside of climate change there has been little progress in identifying and robustly quantifying these limits as they may apply to European agriculture.

Given these difficult conceptual and unresolved aspects of sustainability it is perhaps not surprising to find that the empirical literature which sets out to measure the sustainability of specific agricultural systems is inconclusive. A review of 49 academic and other investigations into the sustainability of farming systems conducted in this project turned up 500 different indicators of sustainability. Of these 202 could be characterised as social, 95 as economic, 198 as environmental, and the final five as 'other'. There is little convergence on a core set of sustainability indicators which should always be included. It was also disappointing to find that the considerable efforts devoted by the European Institutions to define indicator sets, for example the IRENA indicators for the agri-environment, have not found their way to be used as the basis for empirical analyses of agricultural sustainability in academic literature or by governments.

Conclusions drawn from this review of the concepts behind sustainable intensification are:

- Input intensification *per se* is ***not*** the goal, but may well be a consequence of achieving these goals. Although, an input which should be intensified everywhere is knowledge per hectare.
- The prime goals of sustainable intensification are a resource efficient agriculture with significantly higher environmental performance. Ecosystem degradation is itself reducing agricultural productivity.
- Sustainable intensification means improving productivity of crops and animals whilst reducing: the leakages of nutrients, crop protection chemicals and greenhouse gases; soil erosion and biodiversity, habitat and species loss; and expanding conservation outputs of agriculture.
- Because intensity and sustainability of agricultural systems vary enormously and from site to site, sustainable intensification development paths will differ widely between locations, farming systems and individual farms.
- Sustainable intensification will mean increasing agricultural outputs in some cases and conservation outputs in others, and in some situations both.
- It would be helpful if academic and commercial atempts to measure sustainability in agricultural systems were to build on the basis of the official indicator sets.
- More effort should be expended to examine the evidence on environmental thresholds relevant to EU agriculture, particularly those related to climate change.
- In the absence of sufficiently comprehensive or specific evidence on thresholds, then it would be more scientifically defensible to talk about environmental, economic and social *performance* rather than *sustainability*. This would better match the use of legislative standards as proxies for thresholds, as performance below such standards is unacceptable.
- The phrase sustainable intensification can be seen as the latest manifestation of many attempts to demonstrate to farmers that they have a twin role of producing food and environmental services.

Actions to progress sustainable intensification

It has been emphasised that a sustainable intensification path, can only be defined with respect to particular farm systems in specific locations and with respect specific concerns. There is no single and simple formula to indicate the path of sustainable intensification for any farm or group of farms. Achieving it will be a process over time and the actions required could involve participants and stakeholders in agriculture, up and down-stream of agriculture and from other interests in rural communities. The actions are discussed under two headings, collective actions which will have to be taken by public authorities and actions which will primarily be the responsibility of private sector land managers and the other businesses in the food chain.

A key common action required of both public and private sectors is research and development. There is clear evidence that agricultural productivity growth responds to research and development effort. Since the food price spikes of the period 2007-2011 the importance of strengthening the public sector research for agricultural development has been well recognized. It is also now well acknowledged that the target of agricultural R&D has to embrace the twin goals of agricultural productivity and the environmental performance which accompanies agricultural production. This is particularly so for public sector research but it is visible in the private sector too.

Actions for the public sector

The two broad areas where collective societal actions are required are to assemble and publicise the evidence on the economic, environmental and social performance of agriculture, and to put in place, and appropriately resource, the mix of policy measures required.

As far as ***assembling indicators*** is concerned, the Member States and European Union have invested considerable resources over many years to define indicators of economic and environmental performance and to devise methods for collecting and collating the data on a common basis for the EU. Two deficiencies in farm-level data collection identified are the recording of non-agricultural incomes of farming households, and environmental performance at farm level. Wider rural development and agri-environmental policy have become a steadily larger part of European policy yet there has not been a parallel development of the farm-level evidence base to support these policies. This is proving to be a handicap in providing the evidence for policy change.

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There are two other areas where further efforts are required on indicators to guide policy. The first is the development of methodologies and metrics for international comparisons of agricultural sustainability. Without these, for example, it is very difficult to assess the relative environmental impacts of displacing imported protein with EU production. The second is to understand better the relationships between land management practices, the factors which drive them, and the impacts on environmental variables. Monitoring developments is a key part of this process which is all too frequently given low priority by governments.

Policy actions are required for improving both the productivity and the environmental management of agricultural land. Policies are reviewed in the report under the four headings: R&D, education, advice and innovation; environmental policy; agricultural policy; and brief mention of other collective actions to stimulate provision of environmental services. Given the policy decisions and actions already underway, it was concluded that the most important policy development to help EU agriculture onto a path of sustainable intensification must be the further evolution of its agricultural policy.

The phrase sustainable intensification has not been adopted as an explicit target or slogan for the Common Agricultural Policy (CAP). However at the strategic level there is no contradiction between this concept and the current objectives of European agricultural and environmental legislation. Environmental and social considerations have steadily grown in importance in the CAP and this is now the largest operational policy for influencing the rural environment as reflected in the number and variety of measures and in the financial resources available to those measures. What matters therefore is first, how the general objectives are expressed in measures in the regulations, second on how the measures are selected, interpreted and implemented by the Member States, and finally how they then affect farmer behaviour on the ground. It is suggested that for those parts of EU agriculture not currently on a path of sustainable intensification, the principal problems are weakness at the second and third of these stages.

This report concluded that sustainable intensification is a logically correct approach, and that for Europe the emphasis has to be further improvement of the environmental credentials of European agriculture. The 2011-14 reform debate ostensibly gave prominence to the improvement of the sustainability of EU agriculture too, but it is judged not to have advanced very far. It is suggested that at the broad policy level the questions setting an agenda for future reforms of the CAP should include:

- Was the strategy of greening pillar 1 a mistake?
- Has the dilution of greening drained it of impact? Should cross compliance and greening conditions be strengthened?
- Should environmental payments be results-based rather than prescriptive?
- Are the principles which underlie the determination of payment rates for environmental services correct?
- If environmental land management contracts with individual farmers are too costly to administer would it help to operate instead through collectives of farmers at higher, landscape or river catchment scale?
- Is a common European policy for integrating environment into agricultural practice the wrong basis through which to operate, should this be devolved to Member States?
- Are there alternative ways, outside the CAP, for achieving delivery of the environmental services from agriculture? Is more strongly enforced environmental regulation a major part of the answer?

The main controversy about the CAP remains the balance between the unclearly justified direct payments in Pillar 1 and the more purposeful measures in Pillar 2. But whatever the data and the policy instruments, ultimately, achieving a sustainably intensive EU agricultural sector requires the active participation of its farmers.

Actions for farmers and agribusiness

An individual farm, moving towards a path of sustainable intensification will generally have to adjust current practices on their farm so that agricultural productivity improves without detriment to environmental performance, or vice versa. This moves them closer to what can be termed the food-environment production possibilities frontier.

The report discusses five kinds of actions which can be initiated in the private sector.

- The first is the full adoption of one of the many farming systems which have been created specifically for their sustainability attributes: agroecology, biodynamic, organic, integrated and precision farming, and conservation agriculture.
- Second is to opt for specific farming practices which tackle particular problems of sustainability. The report indicates forty-three such practices.
- A third kind of action is to more actively engage in measuring farm-level environmental performance to stimulate and guide action.
- The fourth action is to work collectively or collaboratively in groups of farmers to improve environmental performance.
- The final action considers if significantly higher environmental performance might be brought about through private sustainability certification schemes.

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Case studies

Three case studies were devised to supplement and illustrate this general analysis of sustainable intensification. They were chosen to deal with quite different issues, soils, nutrients recovery and recycling and biodiversity management. They employed quite different analytical approaches, to sustainable intensification. The soils case developed a methodology (based on six measured soil characteristics) to identify soils which could be suitable for sustainable intensification. The results showed 41% of the arable area of the EU25 was estimated to be in this category. At the other end of the scale 4% of the area was classed as unsuitable and suggested for extensification. Of the rest, 43% was deemed unsuitable for intensification as at least one indicator was beyond a threshold, and 12% could be suitable for sustainably intensification with restrictions. The nutrient recovery case study investigated options, including difficult ones of reducing scale and density of livestock production, to reduce nutrient surplus and enable better use of scarce resources. The biodiversity study helped illuminate the variability in biodiversity protection in arable farming. The importance of this observed variability is that it implies that much agricultural production in Europe may be taking place well inside the food-environment production possibilities frontier. This in turn implies that there may be corresponding scope to achieve gains from sustainable intensification which moves farm management closer to the frontier.

Final remarks

The collective actions required to define and measure the environmental performance of EU agriculture are well advanced, although not complete. Equally, the suite of policies to protect the farmed environment through environmental legislation and agricultural policy instruments is well developed. In short, in Europe, broadly we know what the problems are and where they are, and we have policy measures which could contribute to dealing with them, so why is progress to reduce these problems insufficient?

One answer is a misguided concern of the contribution of European agricultural production to global food security. The worry is that by taking measures to improve environmental performance in Europe this will reduce production potential in a world of still growing population and food demand. These fears may be overstated. Europe is a relatively high cost production area and its agricultural exports are of more processed high quality foods and highly developed plant and animal genetics. It is therefore not generally a source of low cost calories for poorest countries. Second, there is a continuing long-term trend in underlying productivity growth which also responds positively to R&D effort. In this context the potential output loss from the further withdrawal of a few percentage points of land to provide biodiversity and water protection could be replaced by a relatively few year's productivity growth. Third, such is the size of food waste in the EU, that the private and public efforts to reduce this could also 'replace' output forgone from some production areas where actions are taken to reduce negative environmental effects of intensive production.

Another answer lies perhaps with the perceptions and motivations of farmers. It is not at all clear that they appreciate the extent of the environmental degradation that has accumulated over the last century, or the potential threat this poses for continued future production. This underlines the importance of continuing the efforts to provide the evidence of this damage, and to put more effort to investigate the extent of environmental change and to improve our understanding of the timescale in which environmental thresholds may be reached.

The two most important lessons of applying the idea of sustainable intensification to European agriculture are that farmers and the public should learn to take a more holistic view of the agricultural and environmental outputs from agricultural land management, and that the key input to be intensified is knowledge.

Summary of areas meriting more research

(and corresponding sections where discussed)

- Internationally comparable indicators of environmental impacts of agricultural production (3.5).
- Social sustainability indicators (4.2.2).
- Detecting the proximity of environmental thresholds in European agriculture and thus boundaries for safe operation (4.2.2).
- Assessing how much of EU agriculture could be classed as currently unsustainable with respect to specified indicators (4.3).
- Inclusion in the Farm Accountancy Data Network (FADN) of a wider range of non-farming income earned by agricultural households (5.1.1).
- Inclusion in the FADN of farm-level environmental performance (5.1.1).
- Completion of the development and compilation of IRENA agri-environmental indicators (5.1.1).
- Reviewing the choices confronting the next reform of the CAP (5.1.1).
- Assessing the potential contribution to farm-based public good provision through actions beyond CAP-based and other public payments (5.1.1).
- The establishment of current levels of land farmed and output produced by 'sustainable farming systems' and their potential to deliver sustainable intensification (5.2 – 5.2.1).
- Finding a framework which could help farmers judge the environmental value and economic cost of adopting practices to improve environmental performance (5.1.2).
- Establishment and benchmarking of practicable farm-level indicators of environmental performance (5.2.3).
- Assessing the scope and impediments to collaborative provision of environmental management by farmers in a naturally defined area (5.2.3).
- Evaluating the past and prospective contribution to improved environmental land management of commercial certification and sustainability schemes.
- The approach developed in our soil case, regardless of any drawbacks, deserves to be taken into account, mutatis mutandis, to conduct an analysis of sustainability of land areas or farms in terms of water quality, GHG emissions and/or biodiversity (6.1).

1
Why sustainable intensification?

The concept of sustainable intensification has come to the fore in recent years as a response to the challenges to ***global*** food security. These challenges are principally continuing population and economic growth in the face of scarcities of agricultural land and water and the dangers posed by climate change, agricultural pollution and biodiversity loss.

There is general consensus that it would be unacceptably damaging to climate and biodiversity if a large expansion of global agricultural production to feed the growing and higher-income population were based on further conversion of forest, grasslands and wetlands. There has been large-scale destruction of these ecosystems over the last 150 years and much evidence to show the biodiversity loss, pollution, and climate impacts of this land use change.

This leads to the conclusion that the next increment in global food output must come from continued intensification of existing agricultural land – but this must be accompanied by a step reduction in the negative environmental impacts of agriculture. These are the arguments which lead ineluctably towards the concept of sustainable intensification of existing agricultural land.

This report sets out to analyse the meaning of sustainable intensification as it affects European agricultural production.

Because the twin processes of expansion of the agricultural area and the intensification of the farming of those agricultural areas have both resulted in a high environmental cost, there is understandably a great deal of nervousness about signaling the need for any further intensification – whatever the adjective attached to it. It is constantly, and rightly, asserted that tackling the issue of global food security must deal with a complex set of factors, not least policies and efforts to contain food consumption growth. Food security is much more than a food production issue. This is most fully argued by Godfray and Garnett (2012). There is no disagreement at all with this assertion yet this report confines itself to issues of agricultural production.

The justification for this focus is, first, a matter of expertise and interest of the organisations and researchers on this project. The prime demand side issues raised for food security are food waste, food consumption and dietary patterns and their effects on human health and well-being (Hawks et al 2012). The policies to deal with these issues concern the behavior of the food processing, distribution and food service sectors and the food purchasing and consumption decisions of the population at large. These are principally organisations and agents beyond the farm gate. The policies available to deal with waste downstream of farming, human nutrition and for example the crop/livestock product balance of diets involve instruments, approaches, institutions and subjects utterly different than the measures directed towards agricultural production and environmental land management by farmers. Therefore for reasons of both expertise and policy focus this report is confined to the production issues raised by sustainable intensification.

A second consideration explaining the narrowed focus on production is that it is judged that *some* global agricultural production growth is essential if the number of under-nourished people is to be reduced. No figure is offered for the necessary scale of such growth. It is observed that projections based on anticipated country-by-country population and income growth, together with likely dietary changes which accompany such development, have suggested increased food production required by mid-century ranging from 70% (FAO 2009) to 100% (Tilman *et al* 2011). However if efforts to unblock development in some of the poorest countries were to succeed, access to food by those currently unable to, might increase consumption growth beyond this range. Acting in the opposite direction, if waste reduction strategies, and human dietary change policies were to be successfully enacted and implemented it is possible that the required expansion of production could be substantially less than these large increases.

However, starting from today's circumstances, further consumption side policies are likely to take many years to agree and implement. They are based on information, education, public health campaigns, and sometimes the use of economic instruments and regulatory controls. For example, the experience of campaigns to reduce tobacco consumption, and the complexities of agreeing national, let alone supra-national or international, guidelines and product labeling to achieve healthy consumption of sugars, fats and salt suggest that these policies may take many years to have significant effects. These are not reasons to ignore such policies; indeed they are reasons to accelerate their uptake.

In the meantime it is observed that no authorities are suggesting that it is conceivable that further increases in agricultural production may not be necessary. Indeed it is observed that considerable international efforts since the agricultural commodity price spikes of the 2007-2013 period have focused on the need to increase agricultural productivity and production. The G8 2009 L'Aquila declaration on food security said: "There is an urgent need for decisive action to free humankind from hunger and poverty. Food security, nutrition and sustainable agriculture must remain a priority issue on the political agenda, to be addressed through a cross-cutting and inclusive approach, involving all relevant stakeholders, at global, regional and national level".

These are the prime justifications that whatever increase in agricultural production that takes place in the next few decades, it is highly desirable that it steers clear of conversion of natural wetlands, grasslands and forest lands into agricultural land and that therefore the necessary intensification of production has least possible negative effects on biodiversity, ecosystem services and climate. In short the intensification must be sustainable.

The principal aims of this report are to:

- explore how to interpret the globally derived concept for a single bloc, the European Union and specifically its agricultural sector;
- deepen understanding of what sustainable intensification means;
- explore policy instruments necessary to achieve sustainable intensification;
- consider how the meaning can be explained in such a way that it affects the behaviour of European farmers;
- give examples of how the ideas of sustainable intensification can be pursued in European agriculture by considering case studies looking at land quality, nutrient management and biodiversity management in agriculture;
- draw up conclusions and recommendations for action.

2
What is sustainable intensification?

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There is no generally accepted definition of sustainable intensification. The term itself originates in the 1990s when development specialists were looking into ways to address growing food insecurity in developing countries (Hazell 1995; McCalla 1994, 1995; N.A.F 1994; Hewitt and Smith 1995 and Pretty and Thompson 1996 *in* Pretty 1997). Much of this literature focused on smallholder agriculture that was typified by low yields with often high levels of environmental benefits (Garnett and Godfray 2012). The term has risen into wider prominence since the international credit crisis and energy and commodity price spikes of 2007. In particular it was headlined in the report of the UK's Royal Society (2009) report into global food security, 'Reaping the Benefits: science and sustainable intensification of global agriculture'.

Garnett and Godfray (2012) provide a wide-ranging discussion of the concept, its origins and usefulness. But they do not supply a definition. Their approach is to emphasise that dealing with global food security means that sustainable intensification must be seen as one element of a constellation of actions which also include considerations of population growth, food consumption, and the social and ethical issues surrounding food production, consumption and rural development. As a consequence, their analysis does not take us very far in developing the practical actions needed to move agriculture, whether globally or in any region, closer to a more acceptable development path. This is why this review has decided to focus on the production and especially the environmental land management aspects of sustainable intensification and to do so for a particular region, the European Union.

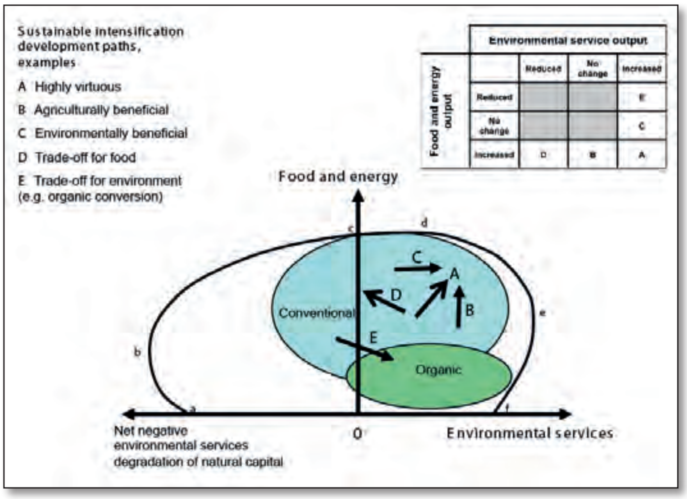
The suggested definition of the term is:

Sustainable Intensification means simultaneously improving the productivity and environmental management of agricultural land.

It is a complex phrase grammatically and part of the difficulty with its use is that important aspects of its meaning are implicit. This contributes to it being easily interpreted in different ways and thus misunderstood. The noun, intensification, describes the result of an action in which some aspect of a system has been intensified. Implicitly, in the context of agriculture, this refers to the need for output of food per hectare of existing agricultural land to rise somewhere in the world. But the critically important adjective in the couplet requires that such intensification must be conducted sustainably. Implicit here are the concerns that much of the existing intensively farmed agricultural land is not being managed sustainably and that further intensification may deepen these concerns. The two component words are teased apart below, but first a simplified model is offered to demonstrate that a sustainable intensification development path of an agricultural system can point in quite different directions depending on the starting conditions.

A way to depict the challenge of sustainable intensification is to use the production economist's device of a production possibility frontier (PPF). This is depicted in Figure 1 below as the line a-b-c-d-e-f. The space is simplified into two dimensions with the provisioning ecosystem services of agriculture (food and energy) shown on the vertical axis, and the environmental outputs of land management, the stewarding of biodiversity and its non-provisioning services (regulating, supporting and cultural) are shown on the horizontal axis. Simplifying further this referred to as the food-environment PPF. To the extent that much agricultural production is held to be environmentally unsustainable this is indicated by the left half of the figure where the pollution and degradation of natural capital are such that the environmental service delivery is negative. A societal goal is to be operating in the right quadrant namely producing food sustainably with net-positive environmental services[8].

Figure 1: *The Food and environment production possibilities frontier (a-b-c-d-e-f)*



Every farm produces a combination of food and environment which is represented as a point in the space of this diagram on, or within, the frontier. The frontier shows, given the current state of technology, the maximum combinations of food and environment that could be produced. In conventional production economics, efficient production implies that all farms should be located on the frontier and in the sector of the PPF with negative slope, i.e. sector d - e[9]. In reality probably very few farms are.

The shaded ovals depict the mass of conventional and organic farms which are operating well within the frontier. The ovals suggest there are wide variations in the both the productivity of food production and the environmental performance in both sectors. The relative positions of the ovals depict the generally higher food output and lower environmental output of conventional farming. The shape of the ovals show more horizontal variation on the hypothesis that as environmental performance is rarely measured and has little economic reward it is likely to be more variable than food production which is measured and is rewarded by markets. The ovals overlap to suggest that there are conventional farms with as good environmental performance as organic, and organic farms with as good food productivity as conventional. These are all testable hypotheses.

The arrows (A to E) show a range of possible farm developments. The concept of sustainable intensification is unambiguously shown by moves A, B and C which all move in the northeast quadrant. Move 'C' depicts farms which improve their environmental performance, with no impact on their food production. This might happen by reducing or eliminating negative environmental effects, thereby moving a farm from the left to right quadrant. Or it may increase the delivery of positive environmental services as depicted in arrow 'C'. A move in the direction of 'B' shows farms increasing their food production with no deleterious (or beneficial) impact on the environment. Move 'A' is the highly virtuous path where both food production and environmental performance can be increased at the same time.

Moves in a northwesterly direction, like 'D', is a classic 20th Century intensification of agriculture which damages natural capital reducing the delivery of positive environmental services increasing the negative services. Indeed arrow D shows farms moving from net positive to net negative ecosystem service delivery. The reverse move 'E' indicates de-intensification of agricultural production, and in the diagram can be interpreted as a farm which converts to organic production – improving the environmental output significantly but diminishing food production in the process.

To the extent that farms in the left quadrant in the diagram are environmentally unsustainable, that is, they are undermining their own ability to continue production

[8] This figure is simplification not to be taken too literally. Furthermore the diagram and text switch freely between distinct concepts of ecosystem services, environmental services, positive and negative environmental impacts, degradation of natural capital and strong and weak sustainability. It tries to bring economic and ecological concepts closer.

[9] In normal production economics, there are marketable goods on the two axes and negative externalities are disregarded so there is no left hand quadrant.

indefinitely, a move like D is unacceptable. However a northwesterly move entirely within the right hand quadrant is another matter, this involves some reduction in environmental performance in exchange for increased food production, but staying in the sustainable quadrant. In the past, production choices have led to sacrifice of some environment for food output. Could this be tolerated in the future? From the perspective of provisioning services, this might be acceptable if other farms making southeasterly moves offset any such northwesterly moves. This is another way of depicting the choice between strong sustainability which does not tolerate any reduction in natural capital/environmental service delivery, and weak sustainability which allows such trade-offs.

Of course technology is not static, and over time new technology, often accompanied by farm structural change, has enabled the production possibilities frontier to move outwards. In the past this has mostly been to push the frontier vertically upwards. However, with more attention paid to research in environmental management, and the delivery by farmers of environmental services it may be possible to tilt the frontier towards environmental gain.

These conceptual depictions of sustainable intensification may be helpful in getting a shared understanding of what it means in the context of food provisioning services and some of the general routes through which it can be achieved. The two most important points to draw from the figure are:

1. *Sustainable intensification does not point to a single development path for all agricultural systems or farms. The direction of the path and the actions required to meet it will depend on the initial conditions, particularly the current agricultural productivity and environmental performance of each farm or system.*
2. *A sustainable intensification path could mean an increase in the output per hectare of environmental services of the farm or an increase in agricultural products, it does not only mean the latter.*

However this conceptual model offers little practical value to the practitioner in the field or those serving farmers up- and downstream, particularly in the context of non-provisioning ecosystem services. More practical implications are discussed in sections 4 to 6 which follow. Before this it is necessary to discuss the general concept of sustainable intensification in the particular circumstances of the European Union.

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3 The EU focus must be on sustainable agriculture

The motivation and prime justification for sustainable intensification is made at the global level. This section considers how it should be interpreted in the specific context of the EU. Five observations lead to the conclusion that sustainable intensification of EU agriculture must place more emphasis on the first word of the couplet.

These are: (i) most of the increased food demand will arise outside Europe. (ii) EU agriculture is already amongst the most intensive in the world. (iii) The European agricultural area has contracted slowly over the last five decades. (iv) Much EU farming fails to meet the environmental standards that the European Union has set for itself. (v) The EU has a large environmental footprint through its agricultural imports. Each of these is examined before the implications are discussed.

3.1 Most growth in food demand will be outside Europe.

Three factors suggest that growth in EU food demand will be relatively slow in coming decades. These are its slow population growth, and in many Member States, declining population, relatively slow economic growth, and dietary patterns and policies. The population of the 28 countries making up the current EU has risen from 373 million in 1950 to 505 million in 2010. UN medium projections for the rest of this century show this peaking at about 520 million in the mid-2030s and then slowly declining to just below 500 million by the end of the century. The picture is very different amongst individual Member States. In particular population is already declining in ten Member States. It is expected to peak and then decline before 2050 in nine others, and it is projected to continue rising throughout the century in the remaining 9 Member States[10]. Economic growth in the EU has slowed since the 2007/8 credit and banking crises, and is not expected to recover fast. In any case the more developed mature economies of Europe systematically show lower rates of economic growth than many non-EU transition and developing countries. In contrast, the research firm Capital Economics forecasts GDP growth in emerging markets overall to be around 4.5% in 2014 — though this is well below their average of 6.0% since 2000 (Time Magazine

[10] Based on UN Population Division (2012). The three groups are as follows. EU countries with already declining population: Bulgaria, Croatia, Estonia. Germany, Hungary, Latvia, Lithuania, Poland, Portugal, and Romania. Projected to peak before 2050 Austria, Cyprus, Czech Republic, Greece, Italy, Malta, Slovakia, Slovenia, Spain. Countries with expected continuing growing population throughout this century: Belgium, Denmark, Finland, France, Ireland, Luxembourg, Netherlands, Sweden and the UK.

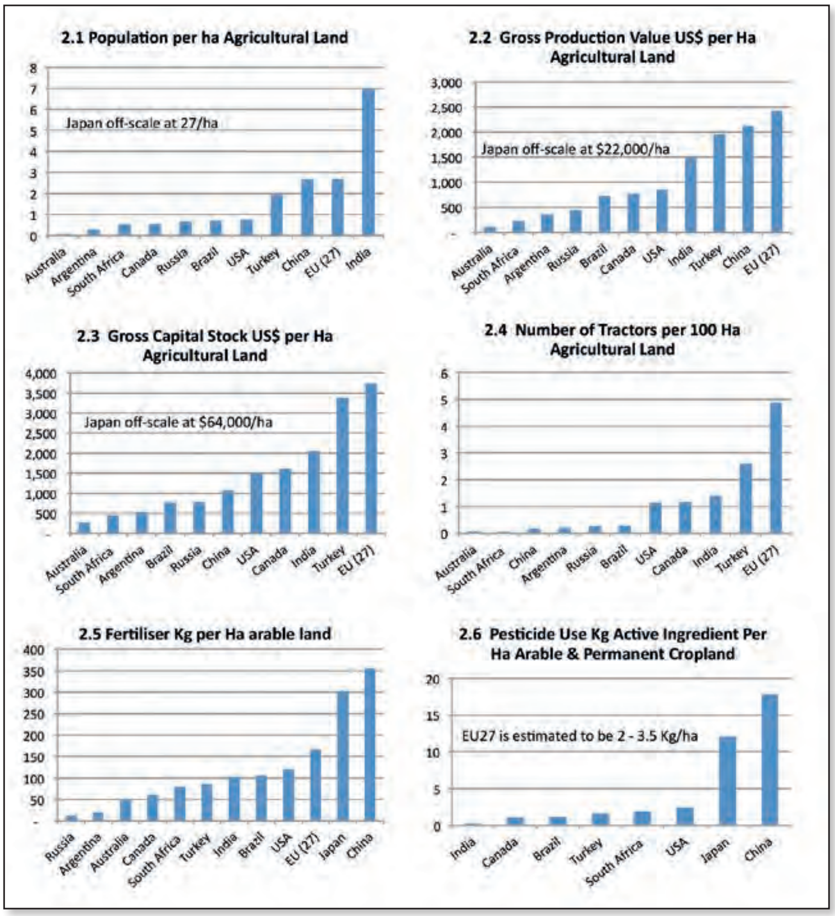
2014). In addition, in most Member States higher incomes do not translate into increases in the volume of food, rather they show up in higher value added, for example as convenience foods and in eating out of the home. The third factor is the process of dietary transition. Europe is already a high consumer of livestock products. For example, every European on average consumes 65 kg of meat (European Commission 2013x) and 280 kg of milk per annum (OECD-FAO 2011), compared to global averages of 42.1(FAO. 2008) and 78 (Chartsbin 2014) kg. Europe also has high levels of food waste. On grounds of both human health and resource efficiency these aspects of food consumption habits are now the subject of systematic efforts to move to what are regarded as more sustainable and healthy diets and to reduce food waste (European Commission, 2011). Together these factors lead to the conclusion that most of the expected growth in global food demand will be outside the EU.

3.2 European agriculture is already highly intense.

Section 4 below discusses the definitions of intensity and sustainability. The focus here is to show, using simple single-factor intensity ratios, that, compared to the world's major producing and agricultural commodity exporting countries, the EU is consistently amongst the most intense agricultural producing countries of the world.

FAOstat data (2013) were compiled for the EU and eleven countries: Argentina, Australia, Brazil, Canada, China, India, Japan, Russia, South Africa, Turkey and the USA. With the EU-27 this group of 38 countries account for 59% of world population, 62% of people engaged in agriculture, over 70% of global cereals, milk and meat production, 64% of global arable land, 63% of capital stock in agriculture, 84% of farm tractors in use and 79% of fertilizer use in the world. Figures were compiled on six ratios. These were: population density per hectare of agricultural land, output value in current (2011) US$/hectare,[11] capital stock in US$ per hectare of agricultural land, tractor numbers expressed per 100 hectares, and two other indicators of what most commentators have in mind when considering intensity of agriculture, namely fertilizer and pesticide use expressed per hectare. The results are shown in Figure 2. The first observation is that the range in intensities is extremely wide, agriculture can be conducted in utterly different circumstances. Where not all eleven countries are shown in the figure this is because the data is not available for that country; in cases where a country is off-scale this is indicated.

Figure 2: *Agricultural intensity amongst the world's largest producing countries*



Based on these simple single-factor indicators of intensity it is plain that the EU, together with China and Japan, have amongst the highest population pressure per hectare of agricultural land and are consequently they are the zones of the most intensive agriculture in the world, amongst these largest market participants. These three are the most intense as far as production value per hectare, capital stock, tractors in use, fertilisers and pesticides[12] used per hectare of land. An initial conclusion is therefore that these countries have less scope for further intensification of agriculture in contributing to future growth in world food consumption.

[11] It is acknowledged that this sums some livestock output and their intermediate feed inputs (which will inflate the figures for countries with large livestock production), but no comparable net production value, or value added figures could be found for all the countries. For the purpose of indicating relative intensity it is considered this is still useful.

[12] The FAOstat data on pesticide application rates are not reliable. There are evidently problems in defining and measuring both the quantities used and the areas over which they are applied. The FAOstat figure for the EU of 93 kg/ha is nonsensical. Private communications with the companies and the Commission suggest the EU figure is more likely to be in the range 2 to 3.5 kg/ha depending on the area used in the denominator. However the conclusion that the EU agriculture is amongst the highest user of these products is likely to be upheld.

It was hoped that this overview analysis of the relative intensity of EU agriculture could be complemented by a comparable analysis of the environmental performance of agriculture in the major producing countries. This proved impossible because no consistent data set measuring the condition of biodiversity, water and soil quality, and atmospheric pollution was found. The only consistently measured environmental indicator was Greenhouse gas emissions from agriculture. This lack of comparable environmental indicators for agriculture is a serious deficiency. Without such indicators, it will be difficult to judge the desirability of policies to move to more sustainable growth paths for any bloc. To explain: suppose it was judged that the EU should de-intensify its agricultural production in order to reduce environmental damage in Europe. If this happened without corresponding efforts to reduce consumption, the EU would import more of its food. Without information on the relative (and marginal) environmental performance of agriculture in exporting countries it is impossible to judge if, globally, this is a preferable state of affairs, or the EU is merely exporting its environmental degradation. As biodiversity loss and climate change are trans-boundary global issues, this is a matter of EU long-run self interest.

3.3 The European area of agricultural land is slowly contracting.

If the prime motivation for interest in sustainable intensification is to avoid the environmentally destructive process of converting natural areas, wetlands, grasslands and forests into agricultural land, then it is of course relevant to examine if this pattern of land conversion is a real and present danger in Europe. The statistics suggest not. Table 1 below shows the historic land cover/land use trends for the EU extracted from a report for the European Commission on land as an environmental resource. It is clear that there is a slow but inexorable process taking place in which the agricultural land area is diminishing. These figures are, of course, of land moving in and out of agricultural production. These changes are the net outcomes of a complex process, which is taking place at different pace across Europe, and over time. But the overall effect is unmistakable. The statistics show that every decade since the early 1960s there has been a fall in the total agricultural area, the arable area, and the permanent grass area for the combined area of the EU27. Over the half century shown in Table 1 these have all fallen by about 14%, that is, about 0.3% per annum. In 2009 there were thirty one million hectares less agricultural land than in 1961. The permanent crop area has also fallen, but at half the rate. Only the forest area has increased. This has all happened whilst the EU27 population rose by 98 million, or 23% percent, over this period and there was substantial real income growth, both contributing to a significant rise in the demand for food.

This release of agricultural land has enabled both the forest area and the area under urban development and infrastructure to rise. These developments have been possible because of the continuous process of technical and structural change in agriculture. The evolution of agricultural productivity in Europe has been closely studied. Wang et al (2012) provide a recent analysis of productivity growth trends in agriculture for many EU Member States. But of course the intensification processes which accompanied these developments have also had profound environmental impacts, analysed in the next section. It is these effects which question if the historic intensification has been sustainable, and point to the need that future such developments focus on their environmental performance.

3.4 European agriculture has damaging environmental impacts.

Farming activities have impact an on all the environmental media – soil, air quality, climate dynamics, water, fauna and flora, and landscapes. As a domain of production, the primary purpose of which is the provision of food, fibre and energy, agriculture both transforms and shapes the management of the natural environment (McKinsey et al, 2011; Krausmann, et al., 2013). The scale of this impact is bound to be large because agriculture occupies such a large proportion of the land area. In the EU the total agricultural area (186 million hectares) is 44% of the total land area, arable land[13] (107 million hectares) occupies 26%. Consequently, it has a fundamental influence on the pattern of resource use, on the functioning of natural systems and the number and abundance of species present in different locations. Due to this interplay between agricultural

13 Arable land is defined as area cultivated at present or within the last five years. http://www.fao.org/economic/ess/ess-publications/ess-yearbook/ess-yearbook2010/yearbook2010-reources/en/

Table 1: *Historic land use trends for agricultural land in the EU-27, 1961 to 2009*

Land use '000Ha	1961	1969	1979	1989	1999	2009	Change
Total Agriculture	219,373	215,230	207,094	202,033	200,238	188,280	- 14%
Arable	128,308	123,122	117,597	115,900	115,631	108,745	- 15%
Permanent crops	12,902	13,409	13,708	13,096	12,699	11,989	- 7%
Permanent grass	78,163	78,699	75,789	73,037	71,908	67,545	- 14%
Forest	-	-	-	135,980	150,963	156,360	+ 13%

management and the natural environment, outcomes for biodiversity, landscapes, soils, water and climate undergo both slow and rapid changes. These interactions are highly complex and are unique to the land management sector of the economy. They are not static, they change over time and they are highly heterogeneous between geographic locations. Simple relationships between farm management and environmental outputs are therefore rare (Baldock, 2012).

Since the 1990s, the view of the relationship between agriculture and the environment in Europe has moved to requirements for a more balanced approach to agricultural and environmental outputs. This was a response to the information about the nature and scale of the pressures assembled and debated in the second half of the 20th century, particularly for arable and intensive agriculture (Baldock, 2000; Stoate et al, 2001; Mazoyer and Routard, 2002; EEA, 2005b, 2009a, 2009b and 2010c; OECD, 2008;

Box 1: *Environmental impacts of EU agriculture*

In relation to biodiversity, agriculture is highly significant as a determinant of species composition and abundance over sizeable areas and the integrity and value of many semi-natural habitats is influenced by farming practice. Major efforts will be needed to reach the EU's target to halt the loss of biodiversity by 2020 and agriculture will have an important role to play. One leading indicator is the population of common farmland birds. This has declined over time but became more stable in recent years. In parallel, the status of rarer threatened farmland bird species continues to be of considerable concern (BirdLife International, 2004). Other, more sensitive, species groups may have declined further, although the data tends to be less good than for birds. For example, data on grassland butterflies continue to show significant declines (more than 50 per cent since 1990). In addition, national reports on the conservation status of species and habitats of Community interest (ie those accorded priority for conservation under the EU's key legislation on this topic, the Habitats Directive) indicate that habitats associated with agricultural activity, particularly grassland habitats, are in poor condition. For example less than 10 per cent of grassland habitats of Community Interest had a favourable conservation status in 2008. More broadly, according to a Commission report published in June 2009, 50% of species and up to 80% of habitats of European conservation interest have an unfavourable conservation status (European Commission, 2009). Overall only seven per cent of habitats linked to agro-ecosystems have a favourable conservation status, compared to 17 per cent for habitat types not related to agro-ecosystems. The reasons for these poor results are, likely to be the shifts towards more intensive agriculture in some areas and, in others, reduced management leading in some cases to outright agricultural abandonment (Baldock, 2012).

Although the EU has made efforts to meet its Kyoto targets, keeping global temperature increases below 2oC is unlikely to be achieved (UNEP, 2013). The State of the Environment Report (EEA, 2010c) highlights the fact that emission cuts of 25-40 per cent will be needed by 2020. The agricultural sector has achieved a significant decrease in GHG emissions by more than 20 per cent since 1990 due to drop in production especially in central and eastern European Member States and overall decrease in animal numbers (EEA, 2010c; Scrieciu, 2011). Adapted land management therefore will have to play a role in further reductions to 2020 and in the next phase of mitigation effort to 2030 and 2050 (UNEP, 2013).

Overall and more positively, the agricultural nutrient balance for nitrogen and phosphorous has improved in recent years for many countries. Nonetheless, diffuse pollution from agriculture remains a major cause of the poor water quality currently observed in parts of Europe. Agriculture contributes 50 to 80 per cent of the total nitrogen load observed in Europe's fresh water (EEA, 2012). Nitrogen loads for the agricultural sector are predicted to remain high over the coming years as increases of 4 per cent in nitrogen fertiliser use are predicted for the EU to 2020 (EFMA, 2009). Linked to this, a study of draft River Basin Management Plans prepared by authorities from all over Europe published before 2009 showed that diffuse and/or point source pollution by nitrogen is reported in 124 out of 137 River Basins reporting to the EU, phosphorous in 123 cases and pesticides in 95 cases (Dworak et al, 2010). The main sources of nitrogen and phosphates are inorganic fertilisers, organic manures and slurries, livestock feed and silage effluent. Indeed, the EEA has stated that 'a significant number of water bodies face a high risk of not achieving good ecological status by 2015' (EEA, 2010c).
The agricultural sector also exerts significant pressure on the quantity of water resources available in many parts of Europe. It is one of the largest consumers of water, utilising a combination of natural precipitation, water abstracted from aquifers and surface sources, and that stored in tanks and reservoirs, for irrigation and use by livestock (WssTP, 2010). On average the sector accounts for 24 per cent of total water abstraction within the EU. However agricultural water use is distributed unevenly, and in some southern European regions it accounts for up to 80 per cent of water extraction. In the context of climate change the problem of water scarcity is of growing concern, and the number of regions experiencing seasonal or long-term droughts has increased over the years (Wriedt et al, 2008; WssTP, 2010).

Although soil degradation processes vary considerably from region to region, and exhibit different degrees of severity, soil degradation remains an issue all over the EU (SoCo, 2009a, 2009b). According to the State of Europe's Soils an estimated 105 million hectares or 16 per cent of Europe's total land area (excluding Russian federation) are at risk of water erosion, and 42 million hectares are affected by wind erosion (Jones et al, 2012). More recent estimates using the "Pesera" model may give a more satisfactory estimate of the area of agricultural land in Europe at risk of soil erosion. The outputs from this model indicate that approximately 57.7 million hectares of agricultural land are at risk of erosion of more than 1 tonne/ha/yr and that 47.2 million hectares are at risk of soil erosion of more than 2 tonnes/ha/yr, with the Mediterranean Member States particularly affected.
An estimated 45 per cent of European soils have low organic matter content (ie have below 3.4 per cent soil organic matter or 2 per cent soil organic carbon), although this varies considerably between regions (SoCo, 2009a and 2009b). In southern Europe, approximately 75 per cent of soils have low organic matter content, partly reflecting the type of the soils, the bioclimatic environment and the extended cultivation periods in these countries. Soils in certain areas of France, the UK and Germany also suffer from low soil organic matter content. Attempts to model the potential risk to soil organic matter from climate change indicate that without changes to management, soil organic matter is at risk on the majority of arable soils across Europe (Gobin et al, 2011). Compaction from regular cultivation and heavy equipment is also widespread although data on the scale of the problem are difficult to obtain.

Stoate et al, 2009). Box 1 provides an overview of these pressures.

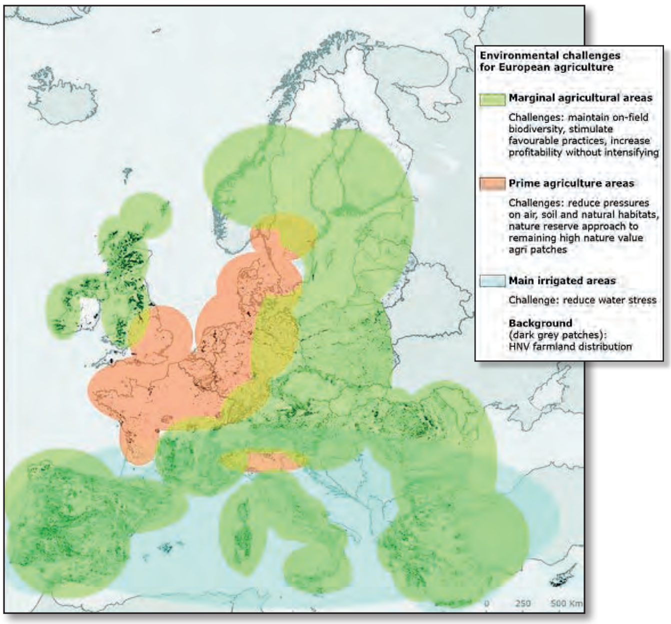
The aspiration of Europeans to introduce targets for mitigation of climate change has increased the attention paid to the emission of greenhouse gases from the agricultural sector and the importance of carbon sequestration in agricultural soils (Schils et al, 2008; Smith, 2012). But there is also an increasing recognition for the contribution of certain land management practices to the provision of ecosystem services, and a greater recognition of the environmental outputs of High Nature Value farming and organic farming. These all illustrate the role of appropriate agriculture in managing the rural environment sustainably. For example, certain improvements have been achieved in some aspects of air quality, local stabilisation of soils, and water quality, and reductions in greenhouse gas emissions from agriculture due to decreased numbers of animals (EEA, 2010c).

The negative environmental impacts of agriculture in the EU have resulted, broadly, from two trends, increasing specialisation, concentration and intensification of production in some areas, and under-management land abandonment in others (Mazoyer and Roudart, 2002; EEA, 2005a; Stoate et al, 2009; EEA, 2010c; Poláková et al, 2011). Such trends are of fundamental importance for the natural environment since each of them results in changes in farm management and farm structures, and frequently also involve the move towards fewer and larger farms.

Intensification, specialisation and concentration of production have been a predominant factor in the increased use of certain inputs with negative environmental effects, particularly, fertilisers, pesticides and mechanization. Accompanying changes in farming practices have also contributed to these effects. These technical and structural changes in farming were of course undertaken as a result of economic pressures – to produce more food and help create economically viable farm businesses. Examples of some of the environmentally damaging practices are: the conversion of grass to arable land, higher stocking densities, the switch from hay to silage making, the use of maize as a fodder crop, and the removal and reduced management of boundary features such as hedgerows, stone walls and other farmland features such as ponds and individual trees (Mazoyer and Roudart, 2012; Farmer et al, 2008; Poláková et al, 2011). These trends in input mix and farm practice change have slowed in the past two decades but it is believed that the less-intensive farming systems, for example in central and eastern Europe, have the potential to undergo further intensification by reversing the low levels of investment in the sector in the two decades following the collapse of communism (Underwood *et al*, 2013).

Just as intensification of agricultural production poses environmental risks, so too does the opposite process. Under-management and the gradual abandonment of farming in some areas tends to reduce the area under grassland and arable croplands, with the accompanying increase in scrub and successive woody vegetation in the landscape, in some situations leading to the deterioration of soil functionality (Cerda, 1997; Pointereau et al, 2008). Whether the habitat changes are beneficial or detrimental to the environment largely depends on their context (Poláková et al, 2011). Large-scale abandonment can lead to declines in habitat heterogeneity and species diversity, which may undermine soil structure across the landscape. In semi-arid areas in particular it can lead to soil erosion since vegetative growth is slow and exposes land to erosion from wind and rain (Cerda, 1997; Pointereau et al, 2008). Small-scale abandonment in open landscapes can lead to improved habitat and species diversity, although generalist species of low biodiversity value are likely to benefit from the change (IEEP and Alterra, 2010). A blend of perceptions linked to the geographic location, cultural heritage and social values in the area, together with the ecological analysis, determine whether or not the changes in the agricultural landscape which result from land abandonment are viewed as positive or negative.

Figure 3: *Environmental challenges for European agriculture*



Source: European Environment Agency (2013)

Reducing the pressures on agro-ecosystems caused by increasingly specialised high yielding systems and maintaining less economic farming systems which produce a high density of environmental outputs, is a dual challenge. This is illustrated in Figure 3, developed by the European Environment Agency. It outlines broad zones across Europe according to a dominant issue for the natural environment. The background depicts the distribution of High Value Nature farmland, particularly low intensity pastures in southern, central and parts of North West Europe. Many of the most valued cultural landscapes and species rich and abundant habitats are found in these areas.

3.5 The EU has a large external environmental footprint.

The EU has a large and relatively open economy and Member States which have long-developed and extensive trading links with the rest of the world. EU agricultural trade accounts for 9.7% and 9.8% of global agricultural imports and exports respectively, by value (European Commission 2012c and Southern African Development Community 2013). It is the world's largest agricultural importer and the second largest agricultural exporter. The EU typically imports fairly unprocessed tropical fruits and beverages, and agricultural commodities particularly soya and maize for animal feeds, and exports higher value products such as wine and other drinks, and processed cereal, meat and dairy products. In value terms the EU has switched recently from a net import to net agricultural export position(European Commission 2012c).

The impacts of agricultural production in other parts of the world which corresponds to the EU's agricultural imports have attracted a lot of attention. It is pointed out that by making these imports the EU is effectively importing land, water and other resources from the producing countries, and also of course in the process, impacting on biodiversity, soils, water, climate and cultural landscape in those countries. This has given rise to investigations of the external ecological footprint of the EU and other trading countries.

There are four main aspects to the EU's external agricultural footprint, the first is the sheer agricultural land area used outside of the continent. According to Noleppa and von Witzke (2008:8), "the currently occupied land in third countries (34.9 million hectares) is almost equivalent to the entire territory of Germany; and the increase of virtual land trade between 1999/2000 and 2007/2008 amounts to 9.6 million hectares which is larger than the land area of Hungary or Portugal".

Second, the external agricultural footprint can be expressed in water terms. The EU is a net water importer. Mekonnen and Hoekstra (2011) estimate that 40% of the water used to produce food for the EU is used outside its territory. There are substantial differences in external water footprints amongst the EU Member States, and some countries, such as Italy, Germany, the UK and the Netherlands, have external water footprints contributing 60% to 95% to their total water footprint. For the EU28 as a bloc the external water footprint for consumption, defined as the sum of direct and indirect water use of foreign water resources through domestic consumption, is 342 km^3 per year (Vanham and Bidoglio 2013). Figure 4 below, from these authors, illustrates the global balances of virtual water encompassed in agricultural and industrial trade.

Third, the external land use footprint has consequences for biodiversity in the areas where land is converted from natural habitat to farmland. Deininger and Byerlee (2011) note that "pastures, natural or improved, account for 3,400 million ha of land use globally and have expanded at about 2.5 million ha/year between 1990 and 2007, with implications for deforestation, biodiversity, and the global carbon balance". However, methods for assessing the costs of these impacts in terms of biodiversity are currently not well advanced. Bertzky et al. conclude that "it is impossible, to date, to arrive at a full picture of where indirect land use change (iLUC) has happened already and how much area has been affected, where it will happen in the future, and what its implications for biodiversity are" (Bertzky et al. 2011:3). They continue: "although additional GHG emissions from iLUC have been considered by various studies (e.g. Searchinger et al 2008), biodiversity impacts of iLUC have so far only been assessed by a limited

Figure 4: *Virtual water balance per country related to trade in agricultural and industrial products over the period 1996-2005.*

Net exporters are shown in green and net importers in red. The arrows show the biggest gross international virtual water flows (> 15 Gm3/yr); the fatter the arrow, the bigger the virtual water flow.

Source: Mekonnen and Hoekstra 2011.

number of modelling studies and empirical assessments are still lacking (ibid.).

Fourth, land use change has consequences for global greenhouse gas (GHG) emissions, as forests are converted into pastures or used to grow crops, a process which switches land from being in equilibrium or a net sink, to being a significant CO2 source. This, too, is an unresolved question. For example, Plevin et al. (2010: abstract) find that "the lack of data and understanding (epistemic uncertainty) prevents convergence of judgment on a central value for iLUC emissions".

How can Europe reduce its external agricultural footprint? The main suggestions in the literature are to reduce food waste, spur dietary change among EU citizens, and increase productivity in European agriculture. Vanham and Bidoglio (2013) argue that "much water can be saved in agricultural production processes, by reducing food waste and by a change in diet of the average EU consumer", while von Witzke and Noleppa (2008:17) hold that "increasing production of agricultural commodities in the EU would significantly reduce net food imports. The analysis presented in this paper also suggests that it would significantly reduce the import of virtual land from around the world. Of course strategies to diminish Europe's domestic agricultural footprint by a shift to less intensive, but lower yielding production practices such as organic production would have the opposite effect". Likewise if the EU land area devoted to bioenergy crops were expanded this would have the same effect.

In debates about the external environmental footprint of EU agriculture particular attention is often given to the 45 million tonnes of feed materials imported to the EU in 2008[14] for the production, consumption and subsequent export of a wide array of animal products. This dependency on imports is particularly evident for protein feed imports for livestock production which were 24 million tonnes in 2008. About 72% of Europe's demand for protein feed crops is met by imports, mainly soy from Brazil, Argentina and the USA. To produce this, an area of 20 million hectares of land outside of Europe is needed, an equivalent to 10% of Europe's own arable land. The remaining 28% of protein feed crops is produced in Europe, and occupies only 3% of Europe's arable land.

Conceptualising and measuring external environmental footprints of agriculture for a country, region or trading bloc is thus at an early stage of development. Land and water footprints are clearly more amenable to measurement. However, it is not clear how valuable these footprints are to steer action. The economic analysis of international trade suggests that the gains from trade arise as it enables countries to specialise and exploit their comparative advantage. This in turn is classically based on factor endowments; countries specialise in and export products which use relatively intensively their abundant factors. Thus land abundant countries export agricultural products. Grasp of this fundamental explanation of the benefits of trade is one of the oldest findings in economics and it is the theoretical underpinning to the post war creation of a rules-based approach to international trade under GATT and then WTO, and trade liberalisation. It is therefore unsurprising to have it demonstrated that large agricultural importers are importing the use of a lot of land!

The sensitive issue is not the trade *per se*, but that outside the economic calculus of consumers and producers in the trading countries are important environmental externalities associated with the underlying production and consumption. It turns out that these external impacts are pervasive and are, or should be, of greater concern both to the producer/exporters, and the consumer/importers. Thus given that the land, and in principle, water markets in South America do, or could, operate reasonably well, it is far more important to know the biodiversity, soil, GHG and cultural landscape 'footprints' of EU imports than their land and water effects.

But even if these more comprehensive external environmental impacts of one county's imports on other countries were available there are some difficult further steps to take action to do anything about them. There are indeed many options. One option for action is to consider if the importing country could displace their imports by less environmentally damaging domestic production. This takes us back to the need for robust indicators of the relative environmental effects of domestic and foreign production. The indicators and data to do this are at a very early stage of development. If such analysis can meaningfully be done it would remain to be shown that the gains from the reduced global environmental damage (by more domestic production) offset the higher costs of local production (which incentivised the imports in the first place!). These are not easy calculations, and supposing it could be convincingly demonstrated that the higher cost of domestic production reduced damage to global ecosystems of a much greater value, it would still remain to persuade domestic consumers of this bargain. They would be asked to pay a higher price for the less environmentally damaging local production.

This in turn indicates a second option for dealing with the damaging externalities of imported produce – to aim at consumers. This means consumer information, labelling, campaigns, sustainable sourcing decisions and choice editing by food manufacturers and/or regulators, and deployment of economic instruments such as taxes, (Hart et al. 2013). A third line of approach is to try and influence the trade flows themselves. This takes us into complex political and legal issues of rules for international trade. A fourth approach is to seek global agreements on matters of the global common good. Indeed this is the approach for biodiversity and climate protection (See box 2, p25 below). It takes a long time to reach such agreements and have them transposed into effective national actions. It

[14] According to Eurostat, imports of animal feed alone were 118 million tons in 2006. I therefore doubt that number.

will be a similarly slow and complex process to agree a fuller range of international environmental standards relating to agricultural production. The fifth, and final approach is to persuade exporting countries to adopt their own higher environmental standards. It is not a straightforward process to instruct other countries how to conduct their affairs, so a better approach might be to do this is by showing their citizens and consumers it is in their own self interest to better protect their environment.

This section has tried to bring together reasoning to determine the broad parameters for interpreting sustainable intensification in the context of the EU. The conclusion is that there are four reasons Europe's role should be to demonstrate sustainable intensification in practice; that is how to combine high intensity, productive agriculture, with high standards of environmental performance. The reasons are that:

- most of the new pressure for additional food production will arise outside the EU,
- EU food production is already amongst the most intensive in the world,
- EU agriculture is associated with pervasive undesirable environmental impacts both in Europe and abroad in countries supplying agricultural exports to the EU
- And in any case, the EU agricultural area is declining and not expanding.

This means that the emphasis in Europe has to be to find ways to continue the process of technical change in food production to radically improve the resource efficiency of European agriculture and in the process to meet European citizens' ambitions for high standards of biodiversity, climate, soil, water and cultural landscape protection. In short, in the EU context, the emphasis in the couplet must be on the first word, sustainability. Defining and explaining this is the task of the next and subsequent sections.

4 Deconstructing sustainable intensification

This chapter teases apart the ideas conveyed by the two component words of the phrase sustainable intensification, and then briefly summarises the point of putting them together.

4.1. Intensity and intensification

Intensity is well defined as a ratio of inputs or output per hectare. It is relatively easily measured but it is generally denigrated!

This is because of concern about the harmful polluting effects of the *some* inputs in *some* circumstances. The conventional approach of intensification has been to raise production yields per unit of land, through greater investment of capital or labour and higher use of purchased off-farm inputs (machinery, fertilisers and crop-protection products) (Montpellier Panel Report 2013). These developments are also often accompanied by structural changes in farming, for example enlargement of farms and fields, changes in land tenure arrangements, and also in the specialization and simplification of farming systems. This intensification of agriculture, most notably during the industrial and green revolutions, led to major increases in yields, but they have, in many cases, also had negative consequences for the environment such as biodiversity and habitat loss, and water, soil and atmospheric pollution which threaten the sustainability of ecosystems. This is the reason for the need to be prudent with the implementation of the concept of further intensification of farming. A cautious approach is needed both to avoid environmentally risky intensification which disregards bio-physical, agronomic and environmental realities of the land, and to avoid overly conservative attitudes to land management seeking environmental protection at all costs.

Intensification and intensive agriculture are thus value laden terms in this debate. They need to be seriously considered because from an agronomic and economic view, these terms are clearly defined technical descriptions of the application of science to agriculture to improve its productivity.

Intensity always refers to a ratio. In agriculture it refers to the ratio of annual *output of product per unit of a particular input over a period of time*. This is most commonly expressed as output per unit of land or per animal, per crop year or lactation. This is what is referred to as 'yields' of, for example, grains, potatoes or sugar measured in tonnes per hectare per year, or the yield of milk measured as litres per cow per lactation. Higher yields indicate more productive and thus more intensive agriculture.

Intensification is a measurement of the productivity of agriculture, rather than a prescribed form of agriculture. More recently, intensity has been also applied to determine ecological parameters of the agricultural production (Barbier and Goulet 2013; De Moraes et al 2014; Goulet 2013). In that sense, intensification also includes a measurement of the rate of production of positive environmental outputs. To intensify agriculture therefore means to make agriculture more productive, either by producing more agricultural outputs by more efficient use of inputs, or in certain situations producing more of the positive environmental outputs from a given area of land. Agriculture must increase its ability to use inputs more efficiently if it is to be more sustainable, impact less on soils, water, biodiversity and climate, and increase production.

Land is the physical basis for measurement, and so most discussions around food production focus on intensity measured as output per unit of land, even though this is just one of the factors of production. Why just land? Food is produced using a long list of 'inputs' from carbon dioxide, water and sunlight to financial services, but land has a unique set of properties. It has physical boundaries, most environmental media (soils, water, biodiversity, landscapes) are intrinsic to it, and its ownership and control is the very cloth of much of human affairs and debate. The importance of land for the debate on food security is also linked to the fact that the area of available land worldwide is more or less finite. However, its capacity to produce is more elastic than has often been assumed possible.

Land is by no means homogeneous – its capacity especially with regard to agricultural productivity varies greatly by location, geology, topography and climate. Whilst the physical area on the planet is finite (though marginally adjustable), its effective usefulness for agriculture is certainly much less constrained than most statements about land suggest. For example, when combined with other inputs – such as know-how, its capacity to produce can systematically grow over very long periods of time, and it has grown many-fold. However, the issue becomes more complex when one considers the combination of bio-physical, climatic and agronomic factors in a particular situation. These factors together, alongside production factors (e.g. know-how), influence the land capability to maintain the production of ecosystem and food services at sustainable levels in long term. For example use of know-how to improve water efficiency alone may lead to higher water use on farm. If it involves extension of irrigated areas this can further aggravate water quantity available to other users and economic sectors in sensitive river basins. So pursuing intensification of environmental services per unit of land is critical, and sustainable intensification must put the task of producing non-provisioning eco-system services alongside the provisioning services of food and energy.

Malthus recognized that the productivity of land could and did rise as population pressure grew. His hypothesis was that the productivity of land is bound to grow more slowly than the tendency for population which grows geometrically (Boserup 1965; Federico 2005). The application of science and technology to agricultural production has enabled agricultural production broadly to keep pace with population growth for the two centuries since his essay (ibid.). However, the environmental costs of this achievement have become increasingly evident. This is why the development of new concepts for viewing the balance of agricultural productivity growth and environmental impacts have been necessary. Discussion of sustainable intensification is a part of this reflection process.

When reference is made to "intensive agriculture" this invariably refers to a ratio of a restricted range of inputs per hectare of land. Intensive agriculture is most frequently thought of as that relating to a narrow group of specific kinds of tangible physical inputs: fertilizers, pesticide[15] and machinery for crop production and housing systems for animals. There are understandable reasons for focusing on these specific inputs particularly because if they are used inappropriately they can become pollutants of water and atmosphere and destroy habitats and biodiversity[16].

However, intensification is not bound to this narrow focus which obscures the fact that developed agriculture uses an increasingly wide range of other 'inputs' not least the genetic materials, seeds, semen, embryos, and plants which are the fruits of crop and animal breeding. This in turn benefits from research and development in crop and animal physiology, biology, biotechnology and increasingly molecular genetics. Other vital inputs into agriculture are provided by: mechanization; energy (solar power directly used by plants in photosynthesis, plus liquid fuels, gas, biomass and electricity); plant and equipment; products, services and processes for plant and animal health; credit, financial capital and insurance; and a wide variety of expert services – agronomic, veterinary, legal, financial, land agency, information and communication technology (ICT) and global positioning systems (GPS); management and marketing. It is only more recently that there has been wider recognition that agriculture also depends on inputs from 'nature', that is, biodiversity and its supporting and regulating eco-system services, such as water availability and quality, pollination, and soil fertility and resil-

15 This is the name commonly used to refer to herbicides, fungicides and insecticides. Scientists, and the industry providing these products, refer to them as crop protection chemicals (CPC) to indicate their purpose more positively.

16 Naturally the widespread application of 'artificial' fertilisers and crop protection chemicals over a significant part of the earth's surface to produce food will raise significant questions about their safety to human health and to the environment, hence the strong regulatory framework which surrounds their licensing and use.

ience. Unfortunately, this recognition has mostly come about because these services have been badly depleted by the over-focus on the man-made inputs.

Economists conventionally group factors of production into land, labour and capital, and therefore talk about labour and capital intensive industries. Note however that the productivity of land can be enhanced by capital investment (e.g. in fertility, drainage and fencing) and labour productivity can be much enhanced by skills and training (often called human capital). Thus a great deal of intensification can and must, in future, take the form of added knowledge embodied in all these inputs and in how they are combined and managed. Similarly, increasing levels of knowledge are needed to manage the ecosystem services on which agriculture relies. Intensification of agriculture, especially in Europe, is therefore not primarily about the use of more fertilisers, pesticides and machinery applied per hectare, but about the development of much more knowledge intensive management of scarce resources to produce food outputs with minimal disturbance to the natural environment.

The knowledge intensity of farming has increased – it is embodied in the purchased seeds, machines and equipment, and applied through the knowledge of farm managers, operators and their advisers. As this happens it proves possible to reduce the quantity of fertilisers applied without reducing yields by better and more precise formulation, placement, and timing of applications. Similarly, crop protection strategies and the control and precision of application of Crop Protection Chemicals has enabled a reduction in the quantity of active ingredient used per hectare. The key point is that the intensity of production (output per hectare) is maintained or increased by increasing intensity of knowledge and technology applied to farming, and at the same time the leakage of the fertilisers and CPCs into the environment is reduced. It is these processes which have to be systematically accelerated and extended.

This discussion has sought to de-stigmatise the word intensification. The prime objective of sustainable intensification is not intensification *per se*, and certainly not an increase in intensity of use of environmentally harmful agricultural inputs. Rather the prime objective is to improve the resource efficiency of agriculture. This language is preferred and indeed the European Union has a road map to steer the process of achieving it (European Commission 2011). Improving resource efficiency means increasing the output per unit of resource use (or reducing the resource input per unit of output). This is what economists define as productivity. Invariably this means that the output intensity especially with respect to the scarcest inputs, e.g. land, will rise. Improving resource efficiency necessarily will show up as in increase of some measure of desirable output compared to some resource (input). Indeed as explained in the introduction, this is the specific motivation for sustainable intensification. What matters is not the intensification *per se*, but its environmental impacts.

Another route to destigmatising the process of intensification would be to place the environmental outputs of land management on an equal footing with the food and energy outputs. Unfortunately the word 'production' has been deeply embedded to refer only to planned outputs which are marketed and sold. It is very hard to imagine that this usage can change, which is a great pity. A great virtue of the relatively new language of ecosystems is that it places the provisioning services of nature, e.g. food and energy which are produced and sold through market-based processes, on the same basis as the supporting, regulating and cultural services, which are not marketed. Indeed the latter are referred to as market failures as they display aspects of public goods[17]. The conceptual framework outlined in section 3 showed how sustainable intensification would and should include examples where there is a rise in the non-provisioning services, i.e. the environmental services, *produced* per hectare. There are many areas of Europe where these ecosystem services have greater social value than the agricultural outputs produced, or producible, for the land. The problem is that because the market processes fail, these services are not valued, or less valued, by producers and so they are consistently undersupplied. A correct interpretation of sustainable intensification should embrace examples where the output or production which is intensified per hectare are the conservation outputs, e.g. pollinators or fledged lapwings per hectare.

In short, high intensity does not automatically mean unsustainable agriculture or unacceptable environmental performance. Where it does, there may have to be some reduction in intensity of the offending inputs. The case studies in Chapter 6 on soil resilience and nutrient surplus in some livestock areas provide examples of this.

4.2. Sustainability and sustainable development

In contrast to the concept of intensity, **sustainability** is not well-defined or measured but is universally supported!

The concept is discussed here under three headings. First the established basis for sustainability in global conventions and EU treaties is reported. Next there is a brief review of four aspects of the concept which cause much discussion. These are: the three pillars of sustainability, strong or weak sustainability, the existence of thresholds, and the scale at which it should apply. Third a review of empirical

[17] RISE 2009 and Cooper et al. 2009 analyze in detail the public goods associated with European agriculture.

work developing sustainability indicators in agriculture is summarised.

4.2.1 Global and EU concepts of sustainability.

The 1987 Brundtland Report defined sustainability as "*meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*". The ideas stimulated by this definition have spawned a large literature, Kaphengst (2014) provides a recent review of these debates in the context of trying to define global sustainable land use.

At the global level, the concept of sustainability emerged in major international initiatives for safeguarding global biodiversity, soils and climate. Signed by heads of states between 1992 and 1994, the Convention on Biological Diversity (CBD), the Convention on Climate Change (UNFCCC) and the Convention to Combat Desertification (UNCCD), signaled the growing awareness of citizens worldwide of the risks of environmental degradation. Agriculture was identified as a sector which both contributes to the problems of biodiversity depletion, climate change and desertification, but is also affected by them. The Rio+20 process, launched in 2012, aims to reinvigorate the goals of sustainable development in all streams of international processes. Box 2 provides an overview.

Box 2: *Elements of definitions of sustainable land use within international processes*

Initiatives promoting sustainable land use were launched in 1990s from several initially separate international processes. The Conventions on Climate Change (UNFCCC) and Biological Diversity (CBD), opened for signature in 1992, and the 1994 Convention on Combating Desertification (UNCCD), encompass the main global initiatives prompted by the Rio Summit in 1992 in response to findings about the greatest challenges to sustainable development.

For funding purposes sustainable land management has been defined in broad and inclusive terms as 'a knowledge-based combination of technologies, policies and practices that integrate land, water, biodiversity, and environmental concerns (including input and output externalities) to meet rising food and fibre demands while sustaining ecosystem services and livelihoods' (World Bank 2006).

Launched in 2012, the Rio+20 summit put a spotlight on the importance of reconciling the environmental and economic goals, and made a new commitment to integrate environmental considerations into economic sectors to achieve 'green growth'. This was highly relevant for agriculture. The new process aims to build awareness about sustainable development which goes beyond various initiatives that are carried out under the existing legally binding international agreements (CBD, UNFCCC and UNCCD) together with the Millennium Development Goals under a separate non-binding agreement.

The purpose of the Rio+20 process is to agree on a suite of measurable goals for sustainable development. Of relevance for agriculture worldwide, the first two goals which have been already adopted include achieving Zero Net Land Degradation (ZNLD) and Zero Hunger Challenge. ZNLD target has been defined as 'the achievement of land degradation neutrality, whereby land degradation is either avoided or offset by land restoration'. While the Rio+20 process has a global participation, the countries who signed it call for 'securing the currently available productive land for the use of present and future generations' (UNCCD, 2012). The outcomes which this international process hopes to achieve on the ground are: zero net land degradation by 2030; zero net forest degradation by 2030; and the implementation of drought policies and drought preparedness in all drought-prone regions/ countries by 2020 (ibid.). However, there is little clarity so far on mechanisms for enabling land managers and farmers to grasp their role in implementing these commitments in practice and on monitoring mechanisms.

In high-level arena of EU policy, the sustainability concept emerged immediately following the release of the Brundtland Report. Since the 1988 EU Declaration on the Environment and the 2001 Göteborg Strategy, promoting sustainable development and sharpening its definition have become the fulcrum of the Community's long-term policy outlook. Box 3 provides an overview of the emergence of the concept of sustainability within the EU high-level strategies.

Box 3: *Emergence of the concept of sustainability in high-level strategies of the EU*

A high-level political agreement by heads of EU Member States supported the adoption of the principle of sustainable development in 1988 in the Declaration on the Environment as an 'overriding objective of all community policies' (European Council 1988). In pursuit of this goal, the Declaration pleaded for new solutions to existing environmental issues 'in the interest of sustained growth and a better quality of life' (Ibid.). In the 1992 Maastricht Treaty of the European Union the term was given prominence in defining the Community objective to achieve 'sustainable and non-inflationary growth respecting the environment' (European Union 1992). From the early 1990s several headline strategies for the EU further elaborated the definition of sustainable growth. With the launch of the Göteborg Strategy on Sustainable Development in 2001 the term was expanded to the triplet of economic, environmental and social sustainability which have to be kept in balance. A particular highlight was put on the fact that 'strong economic performance must go hand in hand with the sustainable use of natural resources' (European Union 2001).

The Göteborg principles were further affirmed in the 2006 EU Strategy on Sustainable Development for the enlarged Union which established the need for a 'break in the link between economic growth and environmental degradation' and proposed ways to achieve this key objective (European Council 2006). The economic pillar aims at 'a prosperous, innovative, knowledge-rich, competitive and eco-efficient economy which provides high living standards and full and high-quality employment throughout the EU'. The environmental pillar promotes 'the capacity to support life in all its diversity, respect the limits of the planet's natural resources and ensure a high level of protection and improvement of the quality of the environment; prevention and reduction of environmental pollution and promotion of sustainable consumption and production to break the link between economic growth and environmental degradation'. The third pillar is defined in terms of social equity and cohesion as 'promoting a democratic, socially inclusive, cohesive, healthy society'. It was however only further developments in sectoral policies that made first steps to define tools and options for the measurement of sustainable growth.

In effect sustainability has become enshrined in the Article 11 of the Treaty of the Union: 'Environmental protection requirements must be integrated into the definition and implementation of the Union policies and activities, in particular with a view to promoting sustainable development' (European Union 2008, article 11).

The EU2020 strategy currently provides the overarching strategic orientations for all EU policies including agricultural policy and brings further refinement to the three pillars of sustainability. It calls for the adoption of measures to make growth sustainable, as well as smart and inclusive, in addition to setting out the objective of growth in terms of 'building a resource efficient, sustainable and competitive economy'. This is foreseen to lead the EU 'to prosper in a low-carbon, resource constrained world while preventing environmental degradation, biodiversity loss and unsustainable use of resources (European Commission 2010).

4.2.2 Four much discussed areas of sustainability.

It is clear that the very definition of sustainability is a normative concept, it is a high level desire or aspiration. But beyond the universal agreement that it is a good thing, lie deep differences in intellectual approach. These differences may explain the sheer difficulty of putting sustainability concepts into practice. Unfortunately they may also present an obstacle to the implementation of derivatives of sustainability like sustainable intensification.

The three pillars of sustainability. It is invariably suggested that sustainability must be considered under the three classic pillars, economic, environmental and social. It is generally suggested that these three must be individually met, and by some, that they should be accorded equal weight. Apart from the difficulty of knowing what it means to give equal weight to these very different aspects of human activity, it is apparent that different interests approach these issues in quite different ways. For example, commercial interests are constantly heard to assert the supremacy of the economic pillar, arguing that without business viability then there is limited capacity for farmers to take care of the environment. But equally strongly felt and expressed is the ecological view that if natural capital is undermined then the long-term survival of businesses cannot be secure. These two positions seem the hardest to reconcile. Their differences emerge again under other issues of sustainability and reflect the fundamentally different paradigms or worldviews from which they come, essentially the economic versus the ecologic. Maybe the strongest that can be said about the three pillars is that all are important but none is paramount.

It has also to be observed that even though lip service is generally paid to the necessity of paying attention to all three pillars, it is often the case that discussions of sustainability focus particularly on the environmental dimension. There is a generally a strong stakeholder representation in most debates for attention to be drawn to the economic dimension. It is the social dimension which generally receives least attention. It has the least well developed conceptual basis. Its concerns can include a wide range of factors which are close to economic (like employment and incomes), but also demographic factors such as age, gender roles and balance, and issues concerning rural service provision, affordable housing, transport, education and health. Ethical issues such as animal welfare is also often considered under this heading. Therefore the meaning of social unsustainability is less clear. Partly as a result of the wide range of issues under the social umbrella there is also less focused stakeholder pressure created to watch out for social sustainability. Although particular interests, such as animal welfare are strongly represented.

Strong versus weak sustainability. The debate about the primacy of the pillars translates directly into different positions taken concerning the degree of substitutability between different forms of capital - physical, financial, natural, human and social, (Costanza and Daly, 1992; Pretty 2008). This seems to be a matter of belief or approach as much of empirical evidence. Supporters of strong sustainability hold that natural capital cannot be substituted by the other forms of capital. This environmental perspective takes the view that the economic system is a sub-set of the natural world. The idea has developed further using the concept of a Constant Natural Capital Rule which sets limits to economic development (Daly 1999) achievable within environmental limits. Supporters of weak sustainability suggest that human well-being can be lifted as development spurs the accumulation of financial, physical, human and social capital at the expense of some diminution of natural capital. In other words – within limits – natural capital can be substituted by other forms of capital. Furthermore they would argue that human well-being has indeed been massively lifted, albeit at the cost of considerable degradation of natural capital. Kaphengst (2014) suggests weak sustainability is associated with growth optimism, seeing natural capital as a production factor and a source for human welfare. Whereas he suggests strong sustainability supporters stress limits to economic growth and see natural capital as a basis for human survival. These are such strong differences in worldview and even philosophical stance that it is hard to see that they could be reconciled, for example by an appeal to evidence.

Does sustainability necessarily imply thresholds? Following from the Brundtland definition, if some aspects of current development are undermining the capacity of the system under question to provide for the needs of future generations, this implies that some threshold, boundary or tipping point has been reached. Furthermore if the diminished capacity cannot be restored, then this implies some irreversibility in the system, or at the very least substantial, perhaps catastrophic, costs to future human well-being. This gets to the heart of the sustainability debate. Strong arguments are made that economic development, including agricultural development, in many parts of the world, are indeed unsustainable. They are compromising future capacity to maintain human well-being. This is evidenced by the extent of pollution of soil, water, the oceans, and the atmosphere, and the depletion of biodiversity and thus the ecosystem services it provides.

For general development the principal area in which substantial research has been done is for climate change where tipping points have been identified such as the melting of polar ice. Rockstrom *et al* (2009) is one of the most quoted sources on environmental thresholds and planetary boundaries. Their research posits important thresholds beyond which non-linear, abrupt environmental change may occur. They then suggest planetary boundaries within which the planet may safely operate. Nine such boundaries are proposed for: climate change, ocean acidification, stratospheric ozone, global nitrogen and phosphorus limits, freshwater use, land system change, biodiversity loss, chemical pollution and atmospheric aerosols. They have proposed physical limits for seven (all but the last two). Their research suggests that three of these boundaries have already been transgressed, namely climate change, biodiversity loss and nitrogen. The analysts are well aware of the uncertainties inherent in the boundaries proposed, and the challenge to interpret them at a regional level.

In view of the importance of the question, there have been surprisingly few attempts to systematically search out and provide evidence of the existence of natural boundaries for agriculture. One study, defined thresholds through linkages between an environmental issue (e.g. soil organic matter level), a pressure (e.g. climate or land management) and/or to an underlying driving force (e.g. economic) (Srebotnjak et al. 2010). Beyond such thresholds, soil and ecosystem degradation which results from the intensification of land use and unsuitable farming practices can significantly reduce agricultural productivity (eg Smith et al. 2010; and more recently EEA 2011; OECD 2011).

Quantification of such thresholds is not straightforward. Simple relationships between human activities and the natural environment are rare. Determining thresholds for individual environmental media which convincingly demonstrate the existence of the irreversibility and damage from exceeding the limit is a considerable challenge. Box 4 below illustrates some proposed thresholds for agriculture. It is interesting that apart from water scarcity the threshold values proposed are based on legislative limits. This is rational and understandable, if these are regulatory limits which farmers are obliged to respect, then it is not unreasonable to suggest them as the boundaries for safe operating space. The presumption is that these legislative levels, which, of course, are determined through a political process were proposed to lie inside any environmental limit thereby building-in a precautionary margin.

Box 4: *Some threshold values for EU agriculture*

A threshold value for water scarcity: It should ideally determine how much water can be extracted and consumed sustainably without causing serious negative and possibly irreversible consequences. The Water Exploitation Index (WEI), developed by the European Environment Agency (EEA), is defined as the mean annual total authorised extraction of fresh water divided by the long-term average freshwater resources. It does not consider yearly and monthly variations. The WEI takes into account only extraction of blue water, and does not address consumption or green water in soils. Severe water stress can occur when the WEI exceeds 40%, and a warning threshold has been recommended at 20%, however the values are under debate (Srebotnjak et al. 2008).

A range of thresholds for water quality exist in relation to nitrogen, phosphorous and pesticide pollution. Two key approaches to defining thresholds for water quality are used in the EU and USA: maximum allowable concentrations of nitrogen and phosphorous, and their total maximum daily loads (Srebotnjak et al. 2008). Member States are currently developing proposals for standards on ecological status under implementation of the Water Framework Directive, including maximum concentrations for phosphorus and nitrogen. The Nitrate Directive further requires a maximum concentration for nitrate of 50 mg/l with a possibility for Member States to set lower permissible thresholds in justified situations.

Threshold levels of soil erosion are typically based on information combining scientific evidence for soil formation and human judgment. EU classification of soil risk based on 'Pesera' model defines an upper limit of 'tolerable' soil erosion at the level of 1 t/ha/year and a serious risk at 2/t/ha/year. Actual soil erosion rates in Europe are on average at a level higher by 3 to 40 times (approx. 3-40 t/ha/yr), and vary across the EU and over time.

The scale at which sustainability applies is a further difficult area. Climate change is clearly a global concern, whereas all other aspects of the environment are considered at continental, regional or local levels. Practical land management is always conducted at local scale yet its impacts may only be measured at a much higher scale, either as a natural region such as water catchment or mountain range, or administrative regions or nation states. Legislative and regulatory action is nearly always determined at the national, or in the case of the EU, supranational, level, although policy may be administered regionally. At which point does it make most sense to measure sustainability? The answer will differ depending on the environmental, social or economic aspect of concern. An activity might be fully sustainable at local scale and yet might be contributing to greenhouse gas emissions which, globally, are rendering other areas unfit for agricultural production. Evaluating thresholds will often depend on local variables since site specific circumstances such as rainfall patterns, soil and climate factors may need to be taken into account. Measurable environmental impacts may take a long time to emerge and may be interlinked with impacts of a number of other economic sectors, policies and other exogenous factors. The relationships between management actions and environmental and social effects may be difficult to establish. Cause and effect may be separate in time and space. Attempts to find thresholds set on the basis of data with low level of resolution may fail to capture point peak pollution or soil deterioration that causes depletion of ecosystems at local or regional level; however, collecting detailed data with high resolution may not be feasible for most environmental media.

4.2.3 Evidence on sustainability in the agricultural sector.

The appreciation that agriculture can play a dual role in providing non-provisioning ecosystem services as well as food, fibre and energy is relatively recent. It requires sharpened knowledge on the ways in which agriculture is embedded within wider ecosystems and the approaches it can use to cope with bio-physical limitations of these ecosystems (Daly 1994; Krausmann et al. 2013).

Sustainability in agriculture must reflect the fact that agriculture affects the status of ecosystems, as well as critically depend on the resilience and continued capacity of these ecosystems to maintain the resource base for food and fibre production in the future. Maintaining this long-term capacity of land, in addition to minimizing environmental deterioration, should therefore be part of the definition of sustainable agriculture (Garnett et al. 2013; Neufeldt *et al.* 2013). This is all the more important given projections indicating that the global agricultural sector is likely to become more market driven in the decade 2013-2022, compared to the previous decades which were shaped by policies and resulted in surpluses in industrialised countries and weak growth in developing ones (OECD-FAO 2013).

The literature reviewed for this study consisted of thirty-eight academic indicator-based investigations of farm or agricultural system intensity and sustainability, nine sustainability certification schemes produced by corporations and political bodies, and two interim reports on experimental farming projects. The review turned up exactly 500 indicators of sustainability in the 49 studies. Sustainability was generally conceptualized as a multi-dimensional phenomenon. But there was some variation in the number of dimensions into which sustainability was divided. Most often this was based on the classic three pillars (e.g. Barnes and Thompson 2014; Gomes-Limon and Sanchez-Fernandez 2010), but sometimes four dimensions were used (Barnes and Poole 2012), or five (Rodrigues *et al*. 2010; Nahed *et al*. 2008), and eleven in the case of Pretty *et al.* 2008. In most cases the indicators cited for these dimensions could be linked back to the core three: economic, environmental, and social sustainability. Classifying the 500 sustainability indicators accordingly, 202 could be characterized as social, 95 as economic, 198 as environmental, and the final five as 'other'. Table 1 shows

the most frequently used indicators of the three pillars of sustainability in the studies reviewed.

Table 2: *Most common three indicators used in agricultural sustainability, by category*

Economic	Environmental	Social
Subsidies	Soil Erosion	Farmer Education
Total output value to total area	Soil Organic Matter Content	Total hired labour to total hours worked
Total subsidies to farm gross margins	Agricultural Nitrogen Balance	Percentage of goods, labour and services sourced locally

Taking the indicators for all aspects of sustainability, the most commonly applied indicator, appeared in just nine of the studies - soil erosion. Three more indicators were applied by seven studies, three by six studies, four by five studies, five by four studies, fifteen were cited by three studies each, and thirty-eight by two studies. The remaining 431 indicators appeared in one study each. Clearly there is a great deal of ingenuity devoted to deciding what sustainability of farming systems should embrace. Table 2 shows the number of times each of the most common indicators were used.

Table 3: *Most common agricultural sustainability indicators, by number of times used*

Indicators	Number of studies
Soil Erosion	9
Farmer Education	7
Soil Organic Matter Content	7
Agricultural Nitrogen Balance	7
Leaching and Runoff of Pesticides to Surface and Ground Water	6
Leaching and Runoff of N/P/K to Surface and Ground Water	6
Soil Cover	5
Emissions to Air	5
Farmer's Age, Years	5
Direct On-Farm Energy Consumption	5
Agricultural Greenhouse Gas Emissions	5
Landscape Elements	4
Amount of water used per ha	4
Farmland birds	4
Pesticides potential impact	4

However the proliferation of and relative ease of conducting multivariate analysis on data sets of sustainability indicators on samples of farms or farm systems has encouraged analysts to investigate many ways of weighting the data to produce a single or smaller number of sustainability indices. The following selection illustrates the range of methods attempted. Yu et al. (1998) use Principal Component Analysis to check how different variables change in relation to each other, or how they are associated. Andreoli and Tellarini (2000:48) suggest two different methods of weighting: the 'weighted sum' ranking method, and the 'best-worst-case' ranking method. Girardin et al. (2000) calculated their indicators at the field level and then averaged over the whole farm. Rigby et al. (2001) assess the impact of the various indicators by identifying from the literature criteria commonly adopted for agricultural sustainability, and then allocating simple scores to each indicator according to whether a particular factor was considered to improve or diminish a farm's performance according to a given criterion. Dias-Balteiro and Romero (2004) weigh indicators according to 'the weight or relative importance attached by an expert or a panel of experts to the individual indicator of sustainability". Zhou et al. (2006) derive the weights of three environmental variables making up the Composite Environmental Indicator by integrating expert surveys with multi-attribute evaluation models such as the analytical hierarchy process. They suggest that if no exact expert information or objective mechanism to determine the relative importance of different environmental variables exist, the choice of equal weights may be more justifiable. Pretty *et al.* (2008) weight the indicators equally within each of their eleven indicator clusters, so a cluster with three parameters would have each parameter contributing one-third to the total cluster score. All indicator clusters could then be summed up to give an aggregate score or index for the agricultural system. Gomes-Limon (2008) weighted the indicators according to three methods: Principal component analysis, the analytic hierarchy process, and a multi-criteria method founded on the concept of the distance to the ideal point. This resulted in the construction of a Global Sustainability Indicator (GSI).

This review has demonstrated that academic work on indicator-based approaches to agricultural intensity and sustainability over the past two decades has moved steadily towards including ever more indicators and ever more sophisticated methods of statistical analysis. As such, this body of literature starkly contrasts similar efforts made outside academia, like corporate environmental certification schemes such as McDonald's (2013), Forest Stewardship Council (2012) and the Roundtable on Sustainable Palm Oil (2013). Broadly, the corporate schemes consist of dichotomous indicators establishing benchmarks to which individual farms and producers should aspire. The possible role for such commercial private sector sustainability schemes is discussed under actions for farmers in section 5.2.5 below.

The work of international organizations', on the other hand, is designed to focus on policy-making. EEA (2005), OECD

(2008) and Ecologic (2010) all base their frameworks on descriptive statistics. Interestingly, Ecologic's report for the European Commission is a rare example which argues that sustainability should be treated as a *threshold* rather than a continuum. The study argues for scientifically established thresholds based on evaluation of individual ecosystems, but they suggest that until such analyses can be carried out on a wider scale, limits established in existing EU, national and local legislation can be used as proxies for thresholds. In this aspect, the EEA's IRENA indicator stands out for its highly elaborated process for environmental indicators. This is discussed under collective policy actions in section 5.1.1 below. At this point it suffices to observe that it is regrettable that practitioners of sustainability indicator sets do not build on the systematic approach to indicator development already undertaken at considerable public expense rather than taking the more *ad hoc* process of re-inventing fresh indicator sets for each new study.

The general impression is that research on the sustainability of agricultural systems makes up a fragmented field, with apparently little convergence on agreed variables to include or methods of analysis. There is a trend towards the development of ever more indicators and more sophisticated statistical techniques to combine them. But knowledge in this area does not seem to have produced practicable and transferable benchmarks enabling the various indices and indicators to be compared. Whilst these studies have often acknowledged, and drawn on the work on sustainability indicators of EU official bodies such as EEA and JRC, these official indicator sets do not seem to have been adopted as the norm. While indicator-based approaches are increasingly getting better at ranking farms, regions, and countries relative to one another within the confines of each study, they are not very helpful yet as tools for public policy-making.

4.3 What do we learn by putting these words together?

More attention to thresholds

The simple global logic behind sustainable intensification is clear. The story becomes more complex when it is applied to the heterogeneous situation of EU agriculture. It has been shown that EU agriculture is amongst the most intense in the world, but just as there are wide variations in simple intensity ratios between the major agricultural producers in the world, there are big differences in intensity between, and within, the Member States, of the EU. Whilst the evidence on intensity is relatively clear and undisputed, this is not the case for sustainability. Can a conclusion be drawn on whether EU agriculture, or significant parts of it, can correctly be described as unsustainable? The literature offers no firm judgment. This seems the only reasonable conclusion at our present state of knowledge. To demonstrate that a system is unsustainable requires evidence that a threshold exists and the system is approaching or has exceeded the threshold. This has not been convincingly done for EU agriculture.

Yet the word unsustainable is, and no doubt will continue to be, used in a looser sense indicating that all is not well. EU agriculture in many places is not satisfying regulatory environmental standards for water quality, particularly diffuse nitrate and phosphate pollution, soil erosion, and the condition of designated sites under the habitats directive. There are well documented concerns about GHG emissions and loss of cultural landscape. On the economic front the sustainability of an agricultural system which is so dependent on public subsidy might reasonably be questioned. The ability and willingness to provide these funds in the EU has decreased and it is far from clear that this funding stream can continue indefinitely. There are deep concerns too about the social sustainability of remote rural communities in areas with highly marginal farming.

Does it matter if the 'S' word is used loosely? One answer is that it most certainly does. Food production is such a fundamental necessity for life that if it is truly the case that certain aspects of farming are unsustainable in the strict sense of the word, then it is vitally important that these instances are detected and steps taken to avoid reaching and passing any irreversible threshold. This indicates that more resources should be deployed to define and discover such thresholds, and devise adjustment paths to avoid reaching them. This should be seen to be in the interests of all, not least those whose livelihoods, and assets, are devoted to agriculture. Such investigations might usefully include detailed review of a range of instances where environmental limits to agriculture were plainly transgressed and agriculture collapsed, the US and Canadian dust bowl of the 1930s and the draining of the Aral Sea are large and graphic illustrations.

The potential existence of thresholds or discoverable environmental limits has three other important implications. First, they will almost certainly be factor and location specific. The problem will be one, or a combination, of factors such as temperature, lack of water, disastrous soil erosion, salinity, pest or disease, absence of pollinators which halt crop production. This implies that the thresholds or boundaries of safe operating space have to be identified factor-by-factor and location-by-location. The scale at which this has to be done is a complex question. Second, for these specific cases where unsustainable practices or systems are exceeding an environmental limit, there will be little or no opportunity to trade off an improvement in some other factor to counterbalance the fact that agricultural production capacity has been lost. Third, it suggests that devoting time to devise sophisticated (or even crude) composite indices of sustainability is of limited use. It is of little use for either a land manager or policy maker to know that the overall sustainability of a system is 55%. What is important is whether and which aspects of the business (or region) are in danger of approaching an environmental limit. The problems will be specific and the actions to remedy them will be specific too.

Environmental, economic and social performance rather than sustainability?

It is possible that even with large resources devoted to searching for environmental limits in agriculture, that these efforts will not produce convincing results. The fact that the investigations to date have fallen back on legislative standards to define safe operating boundaries is revealing. However it surely cannot be a matter for disappointment if environmental limits cannot convincingly be detected? This might be because environmental capacity is more elastic than limits or thresholds suggest. Or it may be that the sheer multi-dimensionality, interactions and dynamism of natural systems, and man's adaptations to them, are so complex that this defies our capacity to demonstrate and measure thresholds. But this does not in any way diminish the importance of knowing whether farming systems are respecting the environmental standards that society has set. These are put in place for the purpose of protecting the environment, and the standards are based on a combination of the science and evidence available moderated through our political processes. If this implies that 'sustainable intensification' really means 'intensification which meets the environmental, economic and social performance standards which society has agreed', it is none-the-less important for that. But the two-word phrase is a neater formulation.

Making a clearer distinction between the strict interpretation of sustainability to mean production well within environmental thresholds, and a looser one which refers to production which respects the environmental standards set by citizens, could command more attention and trust from those who are managing land. There is a danger in repeatedly asserting that farming is unsustainable in the absence of clear evidence of declining productivity that farmers see this as crying wolf. If they believe that they can continue current practices indefinitely and that they are handing their land on to the next generation in good heart, they might reasonably expect convincing scientific evidence to show if this is not the case.

Sustainable intensification may be seen as the latest in a long series of attempts to encourage more integrated land management.

The credibility of the language with the stakeholder group who manage agricultural land is vital if progress is to be made in better integrating the production of food and stewardship of natural capital. This is another reason for pursuing the concept of sustainable intensification. The definition suggested in section 2 above, 'simultaneously improving the productivity and environmental management of agricultural land' was chosen precisely to make explicit that it is necessary both to improve the productivity of food production improving resource efficiency, and at the same time reducing negative environmental impacts and increasing the positive environmental service associated with farming.

This message is not new. Indeed it can be seen as the latest manifestation of a long line of attempts to demonstrate to farmers that they have a twin role of producing food and environmental services. The organic farming movement itself has a long history of developing this idea. Integrated farm management quite explicitly stresses this twin role and has a less restrictive approach than the organic movement to certain inputs.[11] During the 1980s and 1990s in the context of the debates on incorporating agriculture into world trade rules (under GATT and then the WTO) the vogue concept was multifunctional agriculture. More recently this century the emphasis switched to explain to the general public and to farmers their role in producing the public goods associated with good farming. Each of these terms had, and still has, a communication role to explain the multiple outputs of farming. Each reflects the context of their time, and it is no accident that sustainable intensification came into common use in the context of the food price spikes of 2007-11.

The concept can therefore be seen as a way of facilitating the continuing complex task of achieving the better integration of farming and the environment. The above discussion of the term has tried to indicate that:

- The prime goals are a resource efficient agriculture with significantly higher environmental performance. Ecosystem degradation is itself reducing agricultural productivity.
- Input Intensification *per se* is ***not*** the goal, but may well be a consequence of achieving these goals.
- Sustainable intensification means improving productivity of crops and animals whilst reducing: the leakages of nutrients, crop protection chemicals and greenhouse gases; soil erosion and biodiversity, habitat and species loss; and expanding conservation outputs of agriculture.
- Because intensity and sustainability of agricultural systems vary enormously the sustainable intensification development path will differ widely between locations
- This will mean increasing agricultural outputs in some cases and conservation outputs in others.
- The principal input whose intensity will have to increase everywhere is **knowledge per hectare.**

[11] These farming systems, with others are discussed in section 5.2.1 below.

5 Actions to progress sustainable intensification

It has been emphasised that a sustainable intensification path, can only be defined with respect to particular farm systems in specific locations and with respect specific concerns. There is no single and simple formula to indicate the path of sustainable intensification for any farm or group of farms. Achieving it will be a process over time and the actions required could involve participants and stakeholders in agriculture, up- and down-stream of agriculture and other interests in rural communities and in rural land management. The actions are discussed below under two headings, first those collective actions which will have to be taken by public authorities and second the actions which will primarily be the responsibility of private sector land managers.

First however, an important category of actions, which involve both private and public sectors, will be mentioned. This concerns research and development (R&D). It has been stressed that the principal agricultural input whose intensity will universally have to rise is knowledge. It could usefully be sloganized that sustainable intensification is more knowledge per hectare! This has to be brought to bear to continue the process of improving productivity of agricultural production and to do so with significantly reduced negative environmental impacts.

For many decades now the knowledge acquired through public and private agricultural science research, development and extension have been embodied in purchased agricultural inputs to improve the productivity of agriculture. This has involved plant and animal breeding, nutrition and health protection. Farms and farming operations have been mechanized, greatly increasing labour productivity. The fruits of R&D have also been incorporated in human capital as farmers themselves have undergone more, and more formal, education and training. Also a large service sector has emerged around agriculture providing technical, economic and environmental management advice. R&D activity feeds into all of these aspects. In the future knowledge will continue to come from these same sources, although in future it will be important that on all fronts there is greater integration of the economic, environmental and social aspects of sustainable intensification.

The strong and positive connection between agricultural research and development expenditure and growth in agricultural productivity is well established[12] The priority and volume of funds devoted to agricultural research itself has varied over the years. There is little doubt that in the two decades

[12] See Fuglie et al 2012 for detailed analysis of the origins and trends in productivity growth in agriculture in major countries of the world.

preceding the commodity price spikes of 2007-11 a degree of complacency about food supplies had reduced the priority given to public agricultural R&D in many regions. Since that time there has been an upsurge, globally and in the EU, at the very least in political commitment to increase resources allocated to research on agricultural development. It remains to be seen if this translates into action. It is also the case that both public and private sector research have taken on board the message that the objectives of agricultural research have now to pay attention both to the (conventional) productivity of agriculture as well as how to reduce negative environmental effects of agriculture such as soil erosion (Siegrist et al. 1998), the impacts of monocultures (Reidsma and Ewert 2008),biodiversity loss (McLaughlin and Mineau 1995) and the impacts of pesticides (Geiger et al. 2010). It is likely that the public sector will continue to shoulder the responsibility for a greater share of the public good oriented research to improve the sustainability of food production.

The emergence of new farming technologies is partly dependent on public and private willingness to fund fundamental and applied science relevant to animal and plant reproduction, nutrition and growth. But it is also dependent on decisions taken on the licensing of the use of these technologies on farms. The European Union has taken a more cautious approach to licensing the application of certain biotechnological techniques, in particular the development of Genetically Modified Organisms (GMOs) than the other major agricultural exporting countries. It has adopted a similar precautionary approach towards the regulation of pesticides in switching the assessment basis from a risk- to a hazard-based approach. These societal choices influence the range of options farmers have in moving towards a sustainable development path.

It is suggested that, broadly, the amount and makeup of agricultural R&D, and the objectives which have been set for it are not prime obstacles in making progress to set EU agriculture onto a path of sustainable intensification. The more significant challenges are getting the most effective policy framework in place and motivating and enabling land managers to adjust what they are doing. These are the subjects of the next two sections.

5.1. Actions for the public sector and policy

Collective actions are needed first to assemble the national, regional and local evidence on the performance of farming under the three pillars of sustainability to help indicate the areas of difficulty where farms are not achieving their own or societal goals. Such information is essential to help formulate combinations of policy measures to help make the case for and then incentivise farms to change onto development paths which can be described as sustainable intensification. This section deals with each of these two collective actions concerning indicators and policies in turn.

5.1.1 Assembling the indicators for sustainable intensification.

The Member States and European Union have invested considerable resources over many years to define indicators of economic and environmental performance and to devise methods for collecting and collating the data on a common basis for the EU. There is less work conceptualising and collecting data on the social dimension of sustainability.

Economic indicators. The principal farm-level economic performance data are collected under the Farm Accountancy Data Network (FADN).[13] This has steadily developed since its origins in 1965. It is a survey of a representative sample of commercial farms. It currently covers approximately 80,000 holdings, representing about 5 million farms in the EU which occupy about 90% of the utilised agricultural area producing about 90% of the agricultural output. A large amount of data (up to 1000 variables) is collected for each farm. Physical and structural variables include crop areas, livestock numbers, labour, and certain other inputs used. Economic and financial variables include sales, costs, assets and liabilities, subsidies and other CAP related payments. The prime purpose is to provide reliable estimates of the agricultural incomes of farm holdings and to have a representative data set for analysing the impacts (past and future) of the Common Agricultural Policy. The data is collected by agencies in each Member State, usually related to Ministries of Agriculture. It is undoubtedly the most-used source of farm-level management information on the economic sustainability of farming, especially for the agricultural income position of farmers.

The FADN is principally concerned with agriculture, it has slowly extended beyond solely the agricultural income of farms to include some information on certain related activities and diversifications of farmers, for example forestry and tourism. However given that a significant proportion of farmers earn a significant part of their incomes from a wide range of other activities it is an enduring criticism of the FADN that it cannot truly indicate the economic sustainability of farm family households, a significant proportion of whom are pluriactive, because it is only measuring one part of their economic activity. Hill (2012) has consistently made this argument and analysed what is known about the total income of agricultural households.

The other area where the FADN could make a more substantial contribution to help farms find their path of sus-

13 Source: ec.europa.eu/agriculture/rica/concept_en.cfm

tainable intensification concerns farm level measurement of environmental performance. This matter is taken up at greater length below in section 5.2.3 under actions for land managers. The public interest in this is that as agricultural policy has systematically evolved from being a commodity market support system to a policy devoted much more to the market failures concerning social and environmental concerns, the farm-level data collection process has not kept up. This deficiency shows up clearly when it comes to impact assessments of prospective and actual policy change. Europe has invested strongly in the information and modelling systems to measure the farm, sectoral and market impacts of policy change. But it has extremely limited capacity to show the environmental impacts of what has become a much more environmental policy. This has been a handicap in developing the right policy measures. It should be a matter of some urgency because defining and agreeing EU-wide farm-level environmental data requirements takes time and is not cheap. This deficit can be an obstacle to the roll-out of sustainable intensification.

Environmental indicators for agriculture. The European Environment Agency (EEA) is responsible, *inter alia*, for collating and presenting environmental data. In their annual Environmental Indicator report the EEA presents and analyses the state and development of all aspects of the European environment (EEA 2013). This report is based on 146 indicators which are categorized according to the well-established DPSIR model which identifies the focus of the indicator as a Driver (20)[14], Pressures (44), State (23), Impact (40) and Response (19). The Report for 2013 shows twelve indicators which specifically relate to agriculture.

Given that agriculture manages such a significant part of the EU territory (40%) there has been a great deal of work to extend the indicators showing the specific impacts of agriculture on the environment. To this end a large project called IRENA was launched by the Commission in 2002 which culminated in a 2006 communication on 'the Development of agri-environmental indicators for monitoring the integration of environmental concerns into the Common Agricultural Policy (European Commission 2006b). The IRENA indicators were also developed under the DPSIR framework showing the driving forces behind environmental change associated with agriculture, the pressures on the environment as a result of agricultural activity, some environmental benefits from agriculture, and the state/impact on the environment. The IRENA indicators were developed from an idea that in order to be useful, they should contribute to the following criteria:

Simplified description of complex reality

Better communication with non-specialists

Analysis of environmental trends in longer time series

Building a common basis for discussion

Identifying priorities for political decision-making

Once indicators were identified, six criteria were used to evaluate their usefulness; policy relevance, responsiveness, analytical soundness, data availability and measurability, ease of interpretation, and cost effectiveness. To be classified in the highest category, indicators had to show minimum scores; 2 points for policy relevance, 4 points for analytical soundness, and 3 points for data availability and measurability (EEA 2005). The resulting set of 28 indicators is shown in Table 3 below.

There have been varying degrees of success in developing and presenting the data on this set of indicators. Some are fully operational, concepts have been defined, data have been collected at national and sometimes regional level and collated for the EU. Other variables are not available on a harmonized basis across the EU. Others are still being developed. Work is still required at the conceptual and methodological level, in data collections and to extend the indicators to the newer Member States.

This work stream to develop and collect a comprehensive, comparable EU-wide data set on environmental indicators relating to agriculture is a highly ambitious venture. Clearly it has some way to go before the data are fully available for the EU28. In the meantime the data already available for many indicators and for most Member States is sufficient to establish that environmental performance for the protection of soil, water, biodiversity, climate and cultural landscape is inadequate in many parts of the EU compared to the legislative standards and policy targets which have been agreed for these variables. This is amply demonstrated using graphs and maps as discussed in the Environmental Indicator Report for 2013.

Even when the raw information is available there is still considerable work to be undertaken to understand the

14 Numbers in parentheses show how many indicators are in that category.

Table 4: *Agri-environmental Indicators under development by the EU*

Domain	sub-domain	Nr	Title
Respons·es	Public policy	1	Agri-environmental commitments
		2	Agricultural areas under Natura 2000
	Technology and skills	3	Farmers' training level and use of environmental farm advisory services
	Market signals and attitudes	4	Area under organic farming
Driving forces	Input use	5	Mineral fertiliser consumption
		6	Consumption of pesticides
		7	Irrigation
		8	Energy use
	Land use	9	Land use change
		10.1	Cropping patterns
		10.2	Livestock patterns
	Farm management	11.1	Soil cover
		11.2	Tillage practices
		11.3	Manure storage
	Trends	12	Intensification/extensificatio n
		13	Specialisation
		14	Risk of land abandonment
Pressures and benefits	Pollution	15	Gross nitrogen balance
		16	Risk of pollution by phosphorus
		17	Pesticide risk
		18	Ammonia emissions
		19	Greenhouse gas emissions
	Resource depletion	20	Water abstraction
		21	Soil erosion
		22	Genetic diversity
	Benefits	23	High Nature Value farmland
		24	Renewable energy production
State/Impact	Biodiversity and habitats	25	Population trends of farmland birds
	Natural resources	26	soil quality
		27.1	Water quality - Nitrate pollution
		27.2	Water quality - Pesticide pollution
	Landscape	28	Landscape - state and diversity

relationships between land management practices, the factors which drive them, and the impacts on environmental variables. Such information is vitally important for policy determination and design. This work is undertaken through specific research contracts at both EU and Member State level and of course in the academic community. An example where deficiency of evidence on the relationship between farm level practice and environmental outcomes was illustrated in the debates during 2012 to 2014 on the latest reforms of the CAP. Hart (2014) identified points in the negotiations between Council, Parliament and Commission where the Commission's proposals for more demanding greening methods were compromised though lack of objective evidence to support their proposals.

The EU and national level indicators are clearly a vital part of the process of identifying the scale and location of environmental challenges which then inform the policy debate and subsequent policy design. However the information deployed at this level is generally at too coarse a resolution to be of use to practitioners at farm and field level. Identification of sustainability indicators at farm scale, and adoption of appropriate land management approaches by farmers to tackle the risks identified, requires provision of simple methods or data support tools to farmers. For example, farmers will need tools for spatial identification of environmental risks, such as soil erosion risk or state of soil organic matter, or water scarcity (Poláková *et al*, 2013). This is because environmental risks in farming systems, and the priorities for addressing these, vary considerably from place to place, even between different fields on the same holding. Farmers will also want information on the costs and benefits of adopting more environmentally appropriate land management practices. These will significantly affect their willingness to adopt such practices.

5.1.2 Providing the mix of policy measures required.

Collective policy actions are required for both aspects of sustainable intensification: that is improving the productivity and the environmental management of agricultural land. These policies are briefly reviewed under the headings (i) R&D, education, advice and innovation, (ii) environmental policy, (iii) agricultural policy, and (iv) other collective actions to stimulate provision of environmental services.

Research, development, education, advice and innovation. The main collective actions for improving productivity are research, development, education and advice. A good deal of the research and development required to maintain progress in improving agricultural productivity will come from the private sector, particularly the input suppliers providing the genetics, mechanisation, plant and animal nutrition, and pest and disease control, and plant and animal health products. Increasingly these sectors have accepted that building environmental sustainability aspects into their programmes is required. However the main public good oriented research can still be expected to come from the publicly paid research. This takes place for the EU through the programmes managed by the Directorate General for Research and Innovation. The current programme for agriculture and forestry under Horizon 2020 has the following four key headings which indicate the priority to focus research in areas of market failure and public good. The headings are:

- Increasing production efficiency and coping with climate change, while ensuring sustainability and resilience,
- Providing ecosystem services and public goods,
- Empowerment of rural areas, support to policies and rural innovation,
- Sustainable forestry.

In addition the Member States have their own research programmes which reflect their national priorities, and, of course, are designed in the knowledge of the EU programme. It is suggested that in all of these research strands, private and public, EU and Member State, the lesson that sustainability objectives have to be built-in to programmes to stimulate agricultural productivity has been taken on board. That it has to be done is therefore not in dispute. Whether it is being done adequately is another matter. There is likely to be differing degrees of commitment to the twin objectives amongst the Member States, those with lower productivity may still prioritise the increase in yield.

Translating the fruits of the research on combining high performance for the environment and productivity into changed practice on the ground is probably the greatest challenge. This is partly a matter of education, training and advisory services. But it is also strongly linked to farmer motivations and attitudes and the market and policy incentives which confront them. Agricultural education and advisory services are mostly matters for Member States. Debates in agricultural colleges on integrating environment into agricultural curricula have been running for a long time, and again there is a spectrum in the degree to which this integration takes place.

At the EU level the need for advisory services and for innovative approaches is well recognised and is an important dimension of the new Rural Development Programmes to operate from 2014-2020. In particular the European Innovation Partnership (EIP) for agriculture is entitled 'Agricultural Productivity and Sustainability' (European Commission 2012). It seeks to be doubly innovative. First, it is innovative in the way that projects are identified and actioned. This will be done by bringing together groups of stakeholders including researchers, farmers and other businesses, advisory services and NGOs. This is partly in recognition that bottom-up capacity and institution building is a necessary part of generating the understanding and motivation for the degree of integration that is required for sustainable intensification. Second, it is recognised that the innovative projects which the EIP hopes to stimulate will be a variety of approaches which could be technological or non-technological, involving new or traditional practices and operating at a range of scales. This reflects what has been observed about sustainable intensification – its expression can be as diverse as European agriculture is itself. It will not be embraced by a few big ideas, but by the practical application of a multitude of developments.

Environmental Policy. It is suggested that there is no specific new or radically different policy set required to steer EU agriculture to a path of sustainable intensification. Given that the EU comprises a single internal market and that many of the environmental concerns are strongly trans-boundary, environmental policy has been defined at the EU level. Most of this is in the form of Directives setting the regulatory framework and general objectives and allowing Member States to transpose the directive through the appropriate detailed implementation arrangements which suit their institutions, economic circumstances and environmental concerns. Directives most relevant to sustainable intensification of agriculture have been agreed for Birds and Habitats, Nitrates, Water and Sustainable use of Pesticides. The environmental media for which there are no comparable Directives are soils and climate. Lengthy discussions have taken place about the necessity for a soils directive, currently this has not been agreed and policy action on agricultural soils is therefore left to measures under the Common Agricultural Policy and to national measures in the Member States. Policy action on climate protection as it affects agriculture is also currently dealt with through the CAP and through directives on renewable energy. As the reporting of Green House Gas emissions from Land Use, Land Use Change and Forestry and from agriculture develops this could stimulate specific climate policy for agriculture, but this is some way off.

It is generally accepted that the major challenge for European environmental legislation as it relates to agriculture is primarily not whether the Directives are the right ones or whether there are enough such directives but whether they are fully implemented and enforced. There are reasons why this is a difficult process in agriculture. The environmental pollution is diffuse. Potentially it emerges over the whole farmed territory. It is caused by a very large number of very small businesses, and these are often economically marginal and generally have very limited resource and expertise to absorb the detail of the environmental regulation and to respond to it in their business practices. Given these structural characteristics the enforcement costs of such legislation are high, so polluter-pays regulation with sanctions for non-compliance is an approach which does not achieve fast results. This is one of the reasons that high hopes have been vested in using quite different approaches to get better adherence to EU environmental directives by using a variety of instruments of the Common Agricultural Policy.

Agricultural Policy. To date, the phrase sustainable intensification has not been adopted as a target or slogan for European agricultural policy. However at the strategic level there is no contradiction between this concept and the current operational objectives of European agricultural and environmental legislation. The objectives for the CAP defined in the 1957 Treaty of Rome still apply. The first objective is "to increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production...". Together with the other four objectives cited in the Treaty this takes care of the first half of the definition of sustainable intensification adopted in this report. In the 1950s environmental issues were scarcely recognised and so the objectives for the CAP made no reference to the environment. However, environmental considerations were gradually introduced into the CAP from the late 1980s. Lowe and Whitby (1997) and Hart and Baldock (2010) provide accounts of this process. The environment was cemented into EU policies in a more strategic and formal way by the 2001 Göteborg Council, which led to the establishment of the principles of sustainable development within the EU Treaty. Environmental and social considerations have therefore steadily grown in importance in the CAP and this is now the largest operational policy for influencing the rural environment as reflected in the number and variety of measures and in the financial resources available to those measures.

The integration of environmental and social considerations into the CAP is quite explicit in the Commission's three proposed objectives for the CAP in their communication which launched the negotiations of the most recent reform (European Commission 2010b). These are: viable food production, sustainable management of natural resources and climate action, and balanced rural development. At the level of generality of these concepts it is suggested that there is little difference between these objectives and the definition of sustainable intensification suggested in this report. What matters therefore is first, how these general objectives are expressed in measures in the regulations, second on how the measures are selected, interpreted and implemented by the Member States, and finally how they then affect farmer behaviour on the ground. For those parts of EU agriculture not currently on a path of sustainable intensification, the problem is weakness at each of these three levels.

This report is not the place to provide a comprehensive inventory and evaluation of the large number of measures deployed under the two pillars of the CAP and their relationship to the achievement of a high productivity and environment performance. A thorough analysis of the measures under the CAP which affect the environmental performance of agriculture is provided by RISE Foundation (2009) and Cooper et al. (2009). In a forthcoming paper on integrating biodiversity and ecosystem services into European agricultural policy, Buckwell (2014) categorises CAP environmental measures under the three headings:

Environmental conditionality,
Voluntary environmental schemes,
Regional, zonal and farm type specific supports.

The summary of these measures which follows is based on this paper.

Environmental conditionality, from 2015, refers to two sets of conditions applied to the annual direct payments which comprise the bulk of the first Pillar of the CAP. The largest component of direct payments is made up by the basic payments and the conditions which attach to these are termed the cross compliance measures. The second largest part of direct payments is the greening payment which will be paid on condition that three greening practices 'beneficial to environment and climate' are respected. The cross compliance framework comprises a series of Statutory Management Requirements (SMRs) and a series of Good Agricultural and Environmental Conditions (GAECs). The SMRs are existing EU regulations and directives, most of which are environmental including the Birds and Habitats Directives and the Nitrates Directive. The GAECs include good agricultural practices and a series of requirements based on regional and Member State regulations, mostly environmental. These include measures for retaining landscape features, protecting permanent pastures, avoiding encroachment of unwanted vegetation on agricultural land, soil management to reduce erosion and retain soil organic matter, and establishment of buffer strips – mostly for water protection. The three new greening practices are that farmers must maintain crop diversity (avoid mono-cropping), maintain permanent pasture and establish 5% of their arable land as ecological focus area.

These conditions are attached to payments made to the overwhelming majority of European farmers for many of whom these payments form a significant part of their income. The intention was that this would serve to make farmers aware of the impacts of their activities on the environment and incentivise them, and indeed make the resources available to them, to adjust their practices to respect environmental regulations. The purpose of the greening payment introduced in the recent reform, which offers 30% of the total funds available for direct payments, was to ensure "that all EU farmers in receipt of support go beyond the requirements of cross compliance and deliver environmental and climate benefits as part of their everyday activities" (European Commission 2011a).

The intentions of this approach are clear. A consequence of the switch from market policy to direct farmer payments necessitated the construction of a highly elaborate (and expensive) apparatus to make contact with all individual farmers across the EU in order to make the payments. It therefore makes good sense to use this apparatus to impress on farmers the need to improve their environmental sustainability credentials, and to back this with an inspection regime and with the sanction that payments can be reduced or withdrawn if the conditions are not respected. However the enforcement, monitoring and evaluation are weak and from the evidence to date it is hard to demonstrate that this conditionality (in the form of cross compliance) which has been in place for the EU 25 since 2004, has had a significant effect on the quality of environmental land management. At the time of writing the new greening requirements have not yet been defined at Member State level and will not apply until 2015 so it is too early to conclude on their effectiveness. However many commentators have expressed doubts that the benefits will come close to the scale of the total resources devoted to them (approximately €12 billion per year).[15]

*Voluntary environmental schemes***.** It has been suggested that the agri-environment measure, now located within Pillar 2 of the CAP alongside other land management measures, "is the oldest and the single most significant measure for pursuing environmental objectives across the farmed landscape, both in terms of the spatial coverage of schemes and the resources allocated to them" (Poláková *et al*. 2011). It is compulsory for all Member States to make use of this measure, but there is considerable latitude for Member States to decide the objectives of the schemes and the detailed actions offered in their agri-environment schemes. This is necessary to cope with the range of natural conditions and farming systems around the EU. In total about 23% of the funds for Rural Development for the period 2007-13 were committed to agri-environment, and an estimated 7 million agreements cover about 23% of the EU utilized agricultural area. There is considerable variation in the scale of the use of the measure between the Member States.

The variety of ways these schemes can be used is indicated by the four situations analysed by Poláková *et al.* viz:

- Maintaining and, in some cases, restoring, semi-natural agricultural habitats, mostly the extensively grazed high nature value farming systems.
- Beneficial biodiversity management of un-farmed features as well as in-field options in arable farming and temporary grass, and occasionally focus on locally specific habitats and species.
- Enabling continuation of traditionally managed permanent crop systems, olive groves, vineyards, fruit and nut orchards.
- Conversion and maintenance of organic farming.

These agri-environment schemes are not simple to set up and run, either for the administrators or farmers. They work on a voluntary, multi-year, contractual basis. They may offer annual payments for certain management actions or once-off capital grants for investments. The payment principles are established by regulation to be in accordance with WTO Green box rules for non-production and trade distorting support. This limits payments to the income forgone and direct costs associated with the specific environmental actions. These are not simple to calculate or understand, and are in practice are not very sensitive to changing market conditions – features which make farmers cautious about signing up for periods of 5 to 10 years. The provisions for agri-environment schemes continue in the CAP second pillar through to 2020. However because of the introduction of Pillar 1 greening these schemes will have to be modified, not least to avoid paying for the same actions in both pillars.

Regional, zonal or farm type specific supports. A third broad category of CAP measures which can have environmental significance are those which attempt to deal with a large category of farms which have in common that they are economically highly marginal. The principal such measure is the payment to farms in Less Favoured Areas (LFAs). These payments are made to compensate for the natural disadvantages of farming in areas with unfavourable climate, poor soils, high altitude, steep slopes and often remoteness from markets with poor infrastructure.

Economically this is not a particularly rational policy – in

[15] See for example Matthews 2013a.

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any other sector of the economy such businesses would be encouraged to relocate! It is this logic which perhaps indicates the real purpose of such payments. These areas are already subject to depopulation, often especially an outmigration of young people. It is hoped that the LFA payments can contribute to keeping farming and farming communities alive in such areas. The farming systems found are invariably (but not always) low intensity ruminant grazing. Past attempts to help such areas by trying to encourage them to intensify agricultural production have often doubly failed: there is little scope for such productivity improvement precisely because of the disadvantageous conditions, and in the process the drainage, fencing, pasture 'improvement' and higher stocking rates have inflicted significant damage in lost biodiversity and flood protection, and in water pollution and GHG emissions.

These were the reasons that the LFA payments were converted from headage to area basis in the Agenda 2000 reform. However it is still the case that the payments are generally not directly linked to specific environmental management actions. They are seen as supplements to the (usually much larger) direct payments and as a way of keeping farms in business, i.e. focused on economic sustainability. In some circumstances these payments are properly seen as complementary to the agri-environment measures. This can happen for example in High Nature Value land where Member States have made use of the scope to differentiate the payments according to the severity of the natural handicaps to support such farming systems.

Similar principles can also apply to both the specific supports available under Article 68 of the Rural Development Regulation which applied until 2014, and to the use of coupled payments. These specific and coupled supports are sometimes used to bolster aid to certain traditional forms of production or to differentiate payments according to size or location of farms with environmental objectives in mind.

Whilst these zonal or farm type instruments can be used to useful environmental effect there is little guarantee that they always will be, and they can in many circumstances be helping keep in business farms which are still practicing environmentally unhelpful stocking rates and practices. The recent reform of the CAP has added to the potential support for farmers in the less favoured areas (to be redefined based on more objective physical criteria as areas of natural constraints), abolished the Article 68 supports, but greatly extended the scope to use coupled supports.

This summary of the integration of environmental measures into the CAP is by no means exhaustive. It is suggested that some Pillar 1 market regulation measures, for example milk quotas, can have environmental benefits by enabling the survival of dairying in areas where it might otherwise have ceased with loss to the cultural landscape. Also there are a number of other CAP measures in Pillar 2 which have, or could have, positive environmental effects. Two are the development of skills and capacity, and the provision of so-called non-productive investments[16]. Training and provision of advice can, and often does, focus on improving environmental performance of farms and not just their technical and economic performance. So-called, non-productive investments such as scrub clearance, hedge planting, habitat enhancement e.g. recreation of wetlands, and conservation of heritage are all possible and indeed used by some Member States. Other rural development measures which assist rural economic diversification, and the LEADER programme which helps strengthen local participation and communities can also directly and indirectly assist improved environmental land management. A full review of the environmental impacts of the CAP also has to take account of measures deemed environmentally harmful. Economic support for highly intensive environmentally damaging farming systems, and for example irrigation schemes which threaten over-abstraction of water resources.

The development of these measures to enhance environmental performance has been underway in some Member States for two decades, but other Member States are still at an early stage in their use. Formal evaluations of the measures by the European Court of Auditors (ECA) have often produced negative results. For example a report in 2008 asked 'Is Cross Compliance an effective policy?' (European Court of Auditors 2008). The answer was no. The objectives and scope were judged to be unclear, the legal framework too complex, and the auditors found that the Member States did not take their responsibility to implement effective control and sanctions. The 2011 report on Agri-environment, (European Court of Auditors 2011), criticized the lack of targeting and monitoring of environmental effects, along with insufficient clarification, collection of information justification and reporting on outcomes of individual agri-environment schemes. However, other literature provides much evidence of environmental benefits achieved by some of the measures introduced into the CAP. The detailed analysis of Poláková *et al* (2011) shows many documented examples of improvements for biodiversity and ecosystem services.

Buckwell (2014) concluded that, the integration of environment into agricultural policy as far as objectives are concerned is secure. The question remains on delivery. It was clear during the negotiation process in the recent reform that farmers' organisations successfully persuaded politicians to reduce the environmental ambitions in cross compliance and the new greening payments. Ensuring the least impact of the reforms on agricultural production, and simplicity were evidently stronger motives than improving agriculture's environmental performance. Matthews (2013) suggested that whilst the concept of greening may survive "its practical environmental benefits will be negligible". A Defra (2013) analysis estimated net environmental benefits of £1 billion from greening requirements, mostly from EFA. This is less than one quarter of the payments to farmers for the greening. If this transpires in practice it would represent abysmal value for public money.

Using supra-national policy to steer the highly complex task of managing the diverse farmed environment of Europe is bound to be a substantial challenge. It is perhaps not at all surprising that it is a task which takes several decades to mature. It is not clear that the more recent CAP reform decisions are taking EU agriculture in the right direction. Buckwell (2014) posed many questions. Was the strategy of greening Pillar 1 a mistake? If Pillar 1 greening payments represent poor value for money, should they be reduced or withdrawn, or should the conditions be significantly tightened? Should environmental payments be results-based rather than prescriptive? If environmental contracts with individual farmers are too expensive and simply do not work should the process operate instead through collectives of farmers at higher, landscape or river catchment scale? Is a common European policy based on the CAP the wrong basis through which to operate? What are the alternatives? These questions set an agenda for public discussions on future reforms of the CAP.

[16] This choice of language to refer to investments with primarily environmental and social purpose, perfectly illustrates a deep-seated tendency to confine the word 'production' to marketed agricultural products. It would be preferable if it could equally be applied to the production of public goods , i.e. the non-marketed, non-provisioning ecosystem services!

Other collective actions to stimulate provision of environmental services. Perhaps a lesson from the experience of agri-environment programmes in the EU is that they cannot alone provide the scale of public environmental goods sought from agricultural land. Other approaches which are not dependent on public funding, and direct public administration should be actively pursued. A report by the RISE Foundation (2009), categorised and discussed these as follows: direct delivery by clubs and societies, incorporating environmental services into commercially marketed goods and services, most usually food and tourism, and by helping the creation of quasi markets for environmental services, biodiversity offsetting is one such approach.

In summary, this section commenced by arguing that to set farmers onto a course of sustainable intensification requires two kinds of collective action: first the establishment and maintenance of a comprehensive evidence base of the state of the rural economy, environment and society, second, the creation of a well-balanced set of policy measures to incentivize and assist farmers to improve their productivity and their environmental performance. The chapter has explained that the EU has made considerable progress on both of these collective actions. Yet, both are far from complete. There are gaps in the environmental data. Establishing the data for the social sustainability of Europe's rural space is even less developed conceptually and empirically. However perhaps the more important gap is the evidence base on the relationship between specific farming practices and technologies and their environmental impacts. As far as EU agricultural policy is concerned, it is hard to point to specific measures which could assist the adoption of sustainable intensification which are not available, or have not been tried. Rather the problem with, and main controversy about, the CAP remains the balance between the unclearly justified direct payments in Pillar 1 and the rather more purposeful measures in Pillar 2. But whatever the data and the policy instruments, ultimately, achieving a sustainably intensive EU agricultural sector requires the active participation of its farmers, the subject of the next section.

5.2 Actions for farmers and agribusiness

An individual farm, moving towards a path of sustainable intensification will generally have to adjust current practices on their farm so that it improves agricultural productivity without detriment to environmental performance, or vice versa. In terms of Figure 1, this moves them closer to the food-environment production possibilities frontier.

It should be emphasised at the outset that many European farm systems, farming regions and individual farms are sustainable in all senses of the word. Whilst the statistics reveal profound problems of rural poverty and non-viability of farms, environmental degradation and social disintegration in some European rural areas, these problems are by no means universal. The operators' of the sustainable businesses, no doubt, consider their economic performance is acceptable, family succession is manageable, objectively they are not undermining the ecological systems with which they co-exist, and their local communities are not threatened . Such systems of course will have changed over the years and adapted to new technologies, new economic circumstances and changing social structures. This resilience and adaptability of the family farming structure of EU agriculture is claimed to be one of its greatest strengths and is a vitally important aspect of sustainability.

Of course it has to be acknowledged that the economic situation of these apparently 'sustainable' farming systems and farms in Europe is heavily bolstered by the combination of Europe's common external tariff, and generous domestic farm support policy through the CAP. It might be argued that this dependence on enduring public subsidy indicates an underlying economic non-sustainability. The counterargument is that the societal consent to provide this support system has been repeatedly, and explicitly, tested through democratic processes for several decades. Most recently the extended negotiations on the CAP for the period 2014 -2020 tested the legitimacy of both the substantial budget for the CAP, and its objectives and instruments. Clearly this policy represents a common willingness that farming systems satisfying criteria of environmental and social performance may be supported in this way.

How then can farms be distinguished whether they are on a path of sustainable intensification or not? A recent study by Elliot et al (2012) devised a simple set of five criteria covering the productivity of the farms, and their environmental performance with respect to GHG emissions, nitrate losses to water, ammonia pollution and biodiversity. These indicators were all based on data from readily available farm statistics. The study was based on a small sample of 20 UK farms, over a short time interval (2006-2011). It is novel in being amongst the first to try and identify farms on a path of sustainable intensification. A summary table from the study is reproduced as Fig 5 below.

This shows that just one of the twenty farms in the sample was simultaneously improving productivity and environmental performance on all five measures (shown green). Three other farms in this sample were performing well on at least three criteria and moderately on the others (grey) and not badly (red) on any criterion. These analysts concluded that sustainable intensification can usefully be assessed at farm level with readily available information, and that the major driver of farm strategy is economic factors.

Figure 5: *Evidence of Sustainable Intensification on 20 UK farms*

		Food Production	Carbon Footprint	Nitrate losses to water	Ammonia losses to air	Biodiversity
		GJ /ha	kg CO2equiv/ha	kg/ha	Kg/ha	Index
	A1	20%	21%	4%	1%	0
Arable	A2	33%	-2%	-13%	-30%	1
	A3	-19%	-5%	11%	47%	1
	A4	18%	-8%	-23%	-10%	2
	A5	-12%	-	15%	-9%	2
	A6	15%	11%	28%	-12%	-1
	A7	-14%	20%	5%	-8%	0
Mixed	M1	-10%	-1%	-3%	0%	0
	M2	-11%	-5%	-5%	8%	0
	M3	52%	-27%	-13%	-27%	1
	M4	20%	12%	4%	9%	1
Dairy	D1	14%	11%	1%	36%	-1
	D2	26%	19%	9%	29%	0
	D3	5%	1%	4%	1%	0
	D4	11%	8%	21%	30%	0
Livestock	L1	10%	-14%	-17%	-20%	2
	L2	5%	17%	49%	33%	1
	L3	35%	13%	15%	39%	0
	L4	-4%	-1%	-2%	-4%	0
	L5	-20%	-15%	-23%	43%	2

Source: Elliot *et al* (2013)

This section now considers the actions that farmers themselves can take to ensure they move towards a path of sustainable intensification. Five kinds of actions are discussed. The first is the adoption of one of the many farming systems which have been created for their sustainability attributes. Second is the more limited option of adopting specific farming practices which tackle specific sustainability problems. The third section examines whether more farm-level measurement of environmental performance is necessary. The fourth aspect discussed is collective or collaborative action by groups of farmers to improve environmental performance. The section concludes by considering the contribution that private sustainability certification schemes could make.

5.2.1 Adopt a system of sustainable farming

A number of farming systems are explicitly designed by their proponents to satisfy certain aspects of sustainability. A more widespread adoption of such systems could move agriculture to a more sustainable intensification path. These systems are discussed in some detail in Underwood *et al* (2013) in a report for the European Parliament office for Science and Technology Options Assessment. Box 5 summarises the main features of six systems.

Box 5: *Some sustainable farming systems'*

Agroecology:
Definition: Agroecology is the study of ecological processes that operate in agricultural production systems.
Main features: Agricultural systems which harness ecosystem functions to the maximum possible extent, maximising functional biodiversity and strengthening biological regulation in agro-ecosystems, all of which should decrease agriculture's reliance on certain environmentally damaging external, inputs, particularly biocides and artificial fertilisers.
References: Wezel et al. 2013 and Schaller 2013

Biodynamic farming
Definition: Biodynamic agriculture has much in common with organic farming: , and can be understood as a combination of "biological dynamic" agriculture practices. "Biological" practices include a series of well-known organic farming techniques that improve soil health, whereas "dynamic" practices are intended to influence biological as well as metaphysical aspects of the farm (such as increasing vital life force), or to adapt the farm to natural rhythms (such as planting seeds during certain lunar phases).

Main features: Elimination of synthetic fertilisers and pesticides, and controlling and addressing the organic matter cycle in order to improve and maintain soil fertility.
Reference: Ponzio et al. 2013

Organic farming
Definition: A production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony.
Main features: Use of cover crops, green manures, animal manures and crop rotations to fertilize the soil, maximize biological activity and maintain long-term soil health; use of biological control, crop rotations and other techniques to manage weeds, insects and diseases; an emphasis on biodiversity of the agricultural system and the surrounding environment; reduction of external and off-farm inputs and elimination of synthetic pesticides and fertilizers and other materials, such as hormones and antibiotics; a focus on renewable resources, soil and water conservation, and management practices that restore, maintain and enhance ecological balance..
Reference: Gold 2007

Integrated farming
Definition: Integrated farming seeks to achieve an optimal result from both an economic and environmental perspective in the long run.
Main features: Equilibrated nutrient balance; ecological compensation areas on at least 7% of the farm area; diversified crop rotation; soil protection during winter to reduce the risk of soil erosion and nitrate leaching; targeted and restricted application of pesticides.
Reference: Nemecek et al. 2011

Conservation agriculture
Definition: Conservation agriculture systems comprise minimum mechanical soil disturbance, organic mulch cover, and crop species diversification in conjunction with other good practices of crop and production management.
Main features: Continuous no- or minimal mechanical soil disturbance (i.e. no-tillage and direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil; minimum soil disturbance from cultivation, harvest operation and farm traffic, in special cases limited strip tillage);permanent organic soil cover, especially by crop residues, crops and cover crops; diversification of crop species grown in sequence or associations through rotations or, in case of perennial crops, associations of plants, including a balanced mix of legume and no legume crops.
Reference: Nemecek et al. 2011

Precision farming
Definition: Precision agriculture comprises a set of technologies that combines sensors, information systems, enhanced machinery, and informed management to optimize production by accounting for variability and uncertainties within agricultural systems. Adapting production inputs site-specifically within a field and individually for each animal allows better use of resources to maintain the quality of the environment while improving the sustainability of the food supply. Precision agriculture provides a means to monitor the food production chain and manage both the quantity and quality of agricultural produce.
Main features: Information and technology based farm management systems; increasing efficiency by understanding and utilizing within-field variations; aims not to obtain the same yields from every plot of land, but rather to manage and distribute inputs in order to maximize long-term output.
Reference: Gebbers and Adamchuk 2010

Each of these systems has a following of practitioners, and examples can be found in many sectors of European agriculture in most Member States, and indeed around the world. The term organic farming came into existence in the 1930s as most other farmers joined the surge in the use of synthetic inorganic fertiliser and crop protection chemicals which became the mainstay of 'conventional' farming[18]. Of the six farming systems listed, only organic farming has acquired formal recognition and definition in national and European legislation (European Council 2007) and internationally.

The definition of agroecology is still being debated; it has a wide variety of approaches. Biodynamic farming is subset of organic farming in which practitioners follow the prescriptions based originally on the lectures of Rudolf Steiner in 1924. Integrated farming is a more recent development. Its UK organization LEAF (Linking Environment and Farming) was founded in 1991 (European Council 2007), and a European counterpart organization EISA (European Initiative for Sustainable Agriculture) was founded in 2001. The two other systems listed are less tightly described and prescribed.

Versions of all these systems exist in many EU Member States but the specific permitted and disallowed practices can vary. The first three systems come strongly from the paradigm which asserts the primacy of ecological considerations. The last two are rooted in what is often referred to as conventional agriculture and the paradigm which puts business viability first. They are comparatively more recent. Conservation agriculture has developed rapidly in the Americas and is based on low-til and no-til farming often associated with the use of genetically modified corn and soya, and also is associated with 'climate smart' agriculture focusing on GHG emissions. Precision farming has arisen in association with the technologies which make use of global positioning satellites (GPS) and information processing of soil mapping and yield data. Integrated farming lies in between the more formulaic first three and the newer technology inspired last two. It seeks to inte-

[18] Pioneers include King 1911, Howard 1940 and Lord Northbourne 1940

grate conventionally efficient farming with much closer attention paid to the impacts on the environment.

Agroecology, organic and biodynamic systems have a long history of development and considerable efforts have been made to explain their principles and benefits to society at large and to food consumers in particular. The supporters of each of these systems, and Integrated farming too, work hard to promote the system benefits through the labeling and marketing of their produce. These efforts are successful in that the word organic (or 'bio') has become almost a definition of something which is associated as being 'natural, and pure', and therefore assumed to be sustainable. In this way the intention is to internalize the environmental externalities by persuading customers to pay premium prices for the products. By and large this has worked and significant, and generally growing, niches have been established for such products.

In terms of recognition by the public, and the area of agricultural land over which the system is practiced, organic farming has been the most successful to date of these farming systems. However notwithstanding the universally supportive publicity and financial assistance for organic farming, the proportion of agricultural land it occupies in the EU28 in 2012 is still only 4.5%, ranging from 0.5% in Bulgaria to 17.2% in Austria (EEA 2013). Organic production covers most commodities although the penetration has been highest for permanent pastures and sheep production. It is only in the case of organic farming that the adoption of sustainable farming methods has been helped by considerable public financial support for farmers undertaking the conversion period from conventional farming and for on-going maintenance of what is generally a higher cost system.

The supporters of the first four systems tend to take an in-out, whole farm approach. There is usually a strong commitment and belief in the principles of these farming systems, they are not usually adopted primarily for commercial reasons. In contrast, the adoption of conservation and precision agriculture is more likely to be motivated by commercial advantage but with the important bonus of clear environmental benefits too. Because farms practicing these last two systems do not belong to specific associations there is less information on their uptake. Informal evidence suggests they are growing quite rapidly.

It is not possible to quantify with any precision the proportions of farmers, land and produce which are actively engaged in each of the six systems listed above, this is because apart from organic farming none of the other systems are sufficiently well-defined or included in official statistics. There is a presumption that the clear majority of farms, agricultural land and output in the EU are not managed under the principles of any of these systems. The proponents of the first three systems listed are inclined to the view that all farming should, or will eventually have to, move toward the principles they embrace[19]. The supporters of the other systems tend to be less proselytizing in their approach, rather they seek to 'sell' their model on its own merits, for example of reducing costs or harmful environmental impacts.

It cannot be assumed that all farms practicing these systems are automatically ***on*** a path of sustainable intensification, nor that all farms not classified as following these systems are unsustainable. There will be organic farms which are chronically weak economically notwithstanding the premium at which such products sell and the financial support for such farming under the CAP. The indefinite continuation of such farms and the managed ecosystems they are supporting is far from certain. This is a particular problem for High Nature Value (HNV) farming, much of which is organic (Keenleyside et al. 2014). Other, more commercial organic farms might satisfy all the requirements as far as use of mineral fertilisers, crop protection chemicals and animal health treatments and so on, and yet may be deficient with respect to biodiversity, GHG emissions per tonne of product, or cultural landscape management. Likewise, there can be commercial and profitable arable farms practicing highly intense and productive precision farming which have significantly reduced the leakage of nutrients and crop protection chemicals to water and GHG emissions to atmosphere, and yet might be judged still to be deficient in biodiversity and landscape protection. But equally, it bears repetition that just because a farm is not formally amongst one of these categorized systems it does not necessarily meant that the farm is unsustainable. The specifics of the individual case always matter.

5.2.2 Adopt more sustainable farming practices.

Many farmers may not possess the belief, motivation, or investment funds (in the case of precision agriculture) to sign-up to what are thought to be more sustainable whole farm systems described above. This does not preclude them from making adjustments to their farming operations which move them towards a path of sustainable intensification. Each of the above systems themselves is a combination of individual actions which can improve agricultural productivity and resource efficiency, reduce environmental damage or provide more biodiversity and ecosystem service. A report to the European Parliament Office for Science and Technology Options Assessment (STOA) (Underwood *et al* 2013) provides a convenient and comprehensive list of management options which have the capability of improving biodiversity and climate protection. These options were also assessed for their likely impacts on business productivity and profitability. To illustrate, Table 4 shows the land-based management options and Table 5 has a comparable list of livestock and grazing pasture management options[20].

19 A recent example of this view is provided by de Schutter (2010) a UN rapporteur on global food security who favours agroecology, although most of his remarks are focused on the direction of travel of smallholder agriculture in developing countries.

20 Detailed explanatory footnotes have been omitted.

Table 5: *Land-based management options for European agriculture that provide co-benefits for climate change mitigation and adaptation, biodiversity conservation, and productivity*Source: compilation based on Underwood et al (2013). The scoring was carried out based on a review of 95 studies (re climate change) and 135 studies (re biodiversity) spanning the period 2000 to 2013.

Management option	**Potential benefits for:**			
	Climate change Mitigation	**Climate change Adaptation**	**Biodiversity**	**Productivity**
GRASSLAND MANAGEMENT				
Optimising manure application on grassland	**		*	+
Reducing and optimising use of fertiliser on grassland	**	*	*	0/-
Maintaining (protecting and restoring) natural and semi-natural grassland	**	*	**	+/-
Extensive pasture management (decreased grazing density, avoiding overgrazing, mixed stocking, mosaic / rotational grazing)	**	*	**	+/-
Extensive meadow management (late cutting, restricted or no fertilisation)		*	**	0/-
Use a wider range of livestock breeds including traditional varieties			**	-
CROPLAND MANAGEMENT				
More catch crops / green manure	**	**		+
More winter cover crops /bird food crops/overwinter stubbles	*	*	**	+/-
Crop residue management	**	*		+
Diversifying crop rotations	*	**	*	+/-
Under-sowing spring cereals	**			+/-
Greater intercropping	*	**		+/-
Alley cropping (mixed arable and tree crops)	*	*	*	+/-
Zero or reduced tillage	**	*	*	+
Restricting agricultural activities on slopes/contour farming	*	**		+/-
Reducing / optimising use of fertiliser	**	*		+
Introducing vegetated field margins/strips	*	*	**	-
Introducing arable in-field bare patches (eg bird patches)			**	-
Maintaining and enhancing crop genetic diversity; cropping with seed mixtures		*	**	+/-
Using better adapted crop varieties and improving plant breeding		*		+
Introducing improved pest strategies & reduced pesticide use	*		**	+
Modifying sowing dates		*		+/-
Introducing and maintaining permanent ground cover under permanent crops	*	**	*	+/-
Establishing more firebreaks		*		+
LAND USE CHANGE				
Introducing set-aside, rotational fallow	*	*	**	-
Conversion of arable land to grassland [21]	**	*	*	-
Afforestation of cropland/ Woodland creation	**	*	*	-
Establishing and restoring farmland features (hedges, treelines, woodland patches, terraces, farm ponds, stone walls)	*	*	**	0/-
Restoring peatland and wetland (including rewetting of organic soils)	**	*	**	-
Restoring river and riparian wetland in agricultural areas		*	**	0/-
Shifting crop and grazing areas to changed climate zones		*		-

Source: compilation based on Underwood et al (2013). The scoring was carried out based on a review of 95 studies (re climate change) and 135 studies (re biodiversity) spanning the period 2000 to 2013.

[21] In situations where this management action is planned for mitigation and adaptation benefits, it must target specific soils in high risk zones. Where it is planned for biodiversity benefits, the conversion should introduce species-rich permanent grassland.

What stands out from the lists of actions in these two tables is that most of these options are not novel or highly technical. Most do not require large investment, or wholesale change to farming systems. However, the expert judgment behind the assessment of the agricultural productivity impacts of each option indicates that only sixteen of the forty three options shown are likely to have a positive effect on productivity. For twelve of the practices the productivity effect could be positive or negative, seven were assessed to have a zero or negative effect and nothing could be judged for the other eight. These uncertainties perhaps go some way to explain why the adoption of such practices is problematic. Two things which seem to be missing that may provide part of the explanation of why these practices are not more strongly embraced are first that not enough is known and perceived at farm level about the need for them. Second is the question of motivation and who bears the costs of adopting such practices.

It is therefore necessary to give more thought and attention to what information about their farm an individual farmer should have at his disposal to know if his operation is sustainable or not, and in what direction he should move if it isn't.

Table 6: *Key actions for climate change mitigation and adaptation in livestock, grazing land and pasture management*

No.	Key actions	Effect of action on				Prime actor			
		Mitigation	Adaptation	Environmental synergies and trade-offs	Productivity	Farmers	R&D suppliers	Industries	Government
	Livestock management actions								
1	Optimising manure application	**		+/-	+	■			
2	Improved manure processing (including introduction of anaerobic digestion for biogas production)	**	*	+	0	■			■
3	Optimising manure storage and improving outdoor storage facilities	*		+	0	■			■
4	Feeding techniques to improve digestive nutrient capture, changes to livestock diets	*		+	+		■		
5	Adjust dietary intake by livestock or manipulate the rumen	*		0	+		■		
6	Improved livestock breeding [22]	*	*	+	+		■		
7	Improvement of animal rearing conditions/ animal health		**	+/-	+	■			
	Grazing land and pasture management								
8	Reducing and optimising use of fertiliser	**	*	++/-	0/-	■			
9	Maintenance of permanent grasslands/pasture	**	*	++	+/-	■			■
10	Optimising grazing intensity (length and timing of grazing to avoid overgrazing) [23]	**	*	++/-	+	■			
11	Grassland renewal[24]	*		+/-	+	■			
12	Establishing shelterbelts	*	*	+	+	■			■

Source: Compilation based on Underwood et al (2013)

[22] Livestock breeding and its effect on agricultural productivity is the focus of Study 2.
[23] Refraining from grazing during wet periods; applying rotational grazing: animals are regularly moved between pasture areas in such a way as to avoid damage to the turf and optimize forage growth
[24] Actively improving the composition of grassland eg by controlled deferred grazing, overseeding and resowing

5.2.3 Measure then manage.

There are good reasons why most discussions of sustainability devote considerably more time and effort to the environmental than the economic pillar. Indeed it is constantly observed and heard that when the sustainability of a farming system is under discussion attention is invariably focused on the environment to the exclusion of the other two pillars. This is partly because there are sound reasons to expect strong private motives, mechanisms and measures to warn farmers of their economic unsustainability. A prime motive is to be able to pay bills and feed the farmers family. A powerful mechanism is the refusal, or increased cost, of credit. Indicators of economic sustainability are the numerous statistics produced by farm management and farm financial accounts. Considerable efforts are expended to collect, benchmark and publicize farm economic performance, and farmers have reason to notice and respond positively to such information. This is not the case for farm environmental performance.

The field of farm management economics developed rapidly in the post WWII period. Farm surveys were conducted, then systematized and repeated. The data collected was closely analysed and simple-to-use farm planning and management techniques developed. A great deal of this work was done with public support and public farm management advisory services. The Farm Accountancy Data Network (FADN) is a well-developed EU compilation of such farm-level economic data collected on a harmonized basis amongst the EU Member States. It is the most robust and comparable data set of farm financial performance and the data is widely used by farmers, their organisations and advisers. It is also recognized by policy makers at Member State and EU level as the most reliable data set for farm level economics. From this publicly sponsored information provision there has developed many private sector and farmer operated schemes to collect and pool farm management information and establish benchmarks through which farmers can compare their performance with their peers.

Farmers have a direct economic incentive to use their resources to best effect, and there is ample farm economic information available to them to do so. It is generally observed that a high proportion of the most commercial, larger farms producing the bulk of agricultural output do make use of such information. However it is important to note that, despite these impressive strides taken to improve farm business management and the policy encouragement in the EU since the mid-1990s towards a 'market oriented' business-like agriculture, farm surveys show there is still considerable variation in farm financial performance. This applies even amongst farms in similar systems, of comparable size and circumstances. It is also the case that many, especially the smallest, farms do not compile management accounts or make use of such information. There are complex behavioral and structural reasons for this variable performance. But its existence suggests that there may still be considerable room to improve farm economic performance, and in the process the efficiency of their resource use. This could be the greatest source of productivity gain in moving to a path of sustainable intensification.

These points are made at some length to indicate the contrast between the information base available for the economic and the environmental performance of farms. Very little attention has been paid to measuring and benchmarking farm environmental performance. The surveys behind the FADN collect no direct information on farm environmental variables such as water quality, soil characteristics, biodiversity or landscape on farms. Of course some indirect inferences about farm level environmental performance is possible by reference to the levels of use of fertilisers and crop protection products, water and energy, and also from crop yields and livestock stocking rates. Estimates can be made of farm GHG emissions given information on livestock numbers, cropping, manure management and energy and fertilizer use.[25] However no such calculations are being systematically done yet using the FADN farm sample.

This absence of systematic measurement of farm environmental performance seems a serious omission. It is often suggested that businesses cannot manage what they don't measure. Structurally, farming is a highly fragmented and competitive industry characterized by small margins, low returns on capital invested, and chronically low (but volatile) incomes. In such circumstances it is not surprising that farmers should overlook the negative environmental externalities they create, and the positive externalities that they could create, as these impacts do not threaten, or contribute to, their immediate incomes. Thus farmers neither have a strong economic incentive to attend to their environmental performance, nor is there farm-level information or well-established, locally relevant, benchmarks to assist them to improve such management.

Simply measuring farm-level environmental performance is of course only a first step. But it is an essential one. When that performance is found to be deficient in some dimension, the natural next question is what actions have to be taken to improve. Naturally the farmer will want to know what the costs of those actions are and thus how they affect the farm financial performance. Only by having systematic reliable farm-level data can such questions be established.

All this is not to imply that all farmers are unaware of and indifferent to the environment that surrounds them. Most

[25] An on-line calculator for estimating the farm-level emissions of GHG and sequestration carbon in soils and woodland has been available from the Country Land and Business Association of England and Wales since 2008, (CALM – Carbon Accounts for Land Managers). See www.cla.org.uk/calm

farmers are acutely aware that their livelihood depends on their soils, and natural conditions. But they may not be able to detect the cumulative effects of diffuse pollution or biodiversity depletion. There are many farmers who are extremely knowledgeable about and interested in, for example, the wildlife on their farm, and who know and care deeply about the true sustainability of their activities. However the national indicators of environmental degradation indicate that there must be other farmers who are not sufficiently aware of the range of environmental impacts of their activities. One step to remedy this gap in management information is reasonably clear. This is to improve the collection of indicators of environmental performance alongside the indicators of economic performance at individual farm level and establish and publicise benchmarks of acceptable performance. As discussed in the policy section above, there also many ways in which instruments of the Common Agricultural Policy (CAP) can incentivize farmers to be aware of their environmental performance and take steps to improve it.

5.2.4 Work together with other farmers and stakeholders

There are a number of reasons why it could be advantageous to find ways for neighbouring farmers in a catchment or natural area to work together collectively to improve the environmental performance of their activities. One of the most important is that it offers the possibility to find a more ecologically coherent management of a region. It could allow a better alignment between land management decisions and the environmental needs of the catchment or landscape. The overwhelming majority of European farms, are small, so requiring each, for example, to follow the formulaic approach of allocating a specified percentage of their land to be managed for nature may produce a patchwork of unconnected habitat which provides little biodiversity benefit and thus few ecosystem services.

Second, individual farmers may have little interest, knowledge or skills in environmental management. By pooling their efforts those in the neighbourhood with the environmental expertise can take the lead, or the collective can have the necessary skills bought in. This would be unaffordable by the individual farmer. The scale, and connectivity of habitat are important and also place dependent. These are reasons to suppose that by working together on a scale larger than the individual farm will enable more environmental knowledge and skill to be brought to bear and this could ensure that the resource protection and positive environmental management from the collection of farms is much greater than the sum of individual efforts. Whilst for some aspects of environmental management, for example the establishment and maintenance of linear landscape features like hedgerows, the costs may rise linearly with the quantity, for others there could also be significant economies of scale in management which can be realized by collective delivery, not least, for example, in the set-up and design of the appropriate environmental management.

Another area of significant potential gain from collective action is to reduce public transactions costs. Publicly funded agri-environment schemes or other such scheme for payment for environmental services are the main instruments for incentivizing the delivery of environmental public goods. In situations of highly fragmented agriculture with large numbers of small farms the administrative costs of setting up, running and monitoring such schemes can be prohibitive.[26] This is especially true if expert environmental advice is required to help design the right scheme for each individual farm.[27] By dealing with a much smaller number of cooperatives or other farm collective structures the administrative costs for the government agency could be significantly reduced. Not only has the agency fewer contracts to attend to, but also they effectively decentralize much of the detailed decision-making and implementation back to the farm organization. This may also be seen as a benefit to the individual farmers as the detailed planning and execution of the environmental management is negotiated within the farm group between members and employees instead of with officials from a distant bureaucracy. Such collective environmental management arrangements might also lend themselves to greater engagement with local communities and other stakeholders to help establish preferences and priorities for the local environmental and landscape management.

Whilst it is possible to foresee substantial potential benefits from collective environmental management, this will not be applicable in all circumstances. It requires a considerable willingness and trust on the part of farmers to pool decision making with their neighbours. Cooperation and collaboration works extremely well in many Member States, but not all. The structures can take a variety of forms. There is long experience in making them work for input purchasing, for sharing machinery, and for first stage processing of products. There are examples in the Netherlands where agri-environment schemes have operated on a collective basis[28] , and examples are found in Switzerland and Australia. The Dutch government is proposing to extend this experience with the post-2015 round of agri-environment under the new Rural Development Regulation. There will be many challenges to overcome, for example dealing with non-participants in a natural region, allocating the payments in relation to the environmental contri-

[26] This is partly the reason that small farms are to be exempt from the new greening measures in the new direct payments under the CAP.

[27] In the Entry Level Stewardship scheme operated in England since 2004 administrative costs were minimised by providing no advisory input to farmers. They had to select the options they thought best from a menu, and of course their motivation in choosing options was not necessarily what would give the greatest environmental return. Despite the fact that over 60% of the English farmed area was enrolled in such schemes the visible environmental results have not been very encouraging.

[28] See Hodge and Adams 2013, and for a detailed presentation of the Dutch experience see: http://www.waterlandendijken.nl/uploads/i34_presentation_23-05-2012-web_handout.pdf

butions, dealing with non-compliance, and decisions by farmers to exit the collective arrangement mid-contract. However such are the potential environmental benefits, administrative cost savings and reduction in bureaucracy that these approaches are worthy of greater attention.

5.2.5 Join enhanced private and agri-business certification schemes

Section 5.1 summarised the considerable public financial resources being devoted to help farmers improve all aspects of their sustainability. These efforts should make a noticeable difference over time but their dependence on public finances makes them vulnerable to budget cuts in times of recession or as other priorities emerge. It therefore seems sensible to investigate the scope to extend and deepen the role of commercial sustainability schemes to bring about noticeable improvement in productivity and environmental performance of agriculture.

There are a large range of private sustainability schemes covering agricultural production and products in Europe. Figures are not available about the coverage of all these schemes, but for some commodities or farm types they may embrace a high proportion of production so the combined reach of these schemes over EU agriculture could be considerable. Some of these schemes are national others international in scope, some cover multiple commodities, others are devised for specific commodities. They cover a range of aspects of sustainability. They come from a variety of different origins. Some have been brought into being by farmers' organisations, others by agri-business upstream or downstream of farming and others by a combination of stakeholders. Table 6 indicates some of these schemes and their characteristics.

There is a range of motivations for these schemes. Most aim to raise product standards under a number of headings, and to ensure reliability and consistency of standards to provide quality assurance to consumers. Most of these schemes make reference to sustainability, some very explicitly in their title. They are certainly seen as part of corporate social responsibility actions of companies. There are several strong advantages, actual or potential, from the engagement of such schemes in encouraging farming to a path of sustainable intensification. First, farmers may see the fact that they are independent of government as a benefit as this takes them outside official red tape and bureaucracy.[29] Second these schemes are not dependent on public finances so are not as vulnerable to public budget cuts. Third, farmers may see them as part of normal commercial relationships with their input suppliers or purchasers of their produce. The reach of the schemes can therefore cover a high proportion of production, and there is generally a reasonable degree of trust between the parties. How trusted are private sustainability schemes? To answer this question, a project called 'Rate the Raters' conducted by SustainAbility polled 850 sustainability experts across 70 countries and multiple sectors.[30]

Table 7: *Examples of five private sustainability schemes*

Scheme	Commodities	Number of Indicators	Aspects of Sustainability
Red Tractor – Beef & Lamb	One or a combination of fresh produce, combinable crops, chickens, pigs, beef, lamb	217	Organisation, Management/Planning Human and Social capital Water Use and Protection Climate Change and Air Quality Soil Management Crop Nutrition Crop Protection Animal Husbandry/Animal Health Energy Use and Efficiency Landscape, Wildlife and Biodiversity Resource Management, Product Storage/Waste Disposal
Basel Criteria for Responsible Soy Production	Soy beans	37	Legal Compliance Technical Management Environmental Management Social Management Continuous Improvement Traceability
Roundtable on Sustainable Palm Oil	Palm oil	138	Commitment to transparency Compliance with Applicable Laws and Regulations Commitment to Long-Term Economic and Financial Viability Use of Appropriate Best Practices by Growers and Millers Environmental Responsibility and Conservation of Natural Resources and Biodiversity Responsible of Employees and of Individuals and Communities Affected by Growers and Millers Responsible Development of New Plantings Commitment to Continual Improvement in Key Areas of Activity
Protected Harvest	Mushrooms	25	General Operations Soil and Water Management Air Quality Management Integrated Pest Management
Protected Harvest	Coffee beans	56	General Documented Control System Identification of Certified Inputs and Certified Outputs Handling Requirements from Cherry Progression to Green Coffee Confirmation of Inputs, Storage of records

The experts questioned had a minimum of three years experience, with 60% having a decade or more, and they were asked who they trust most to judge a company's sus-

29 Whether this hope is borne out by experience can be another matter. The inspection and certification processes of private schemes can be as, or even more, onerous than the comparable processes of government agencies.

30 http://www.theguardian.com/sustainable-business/blog/value-corporate-sustainability-ratings-rankings

tainability performance. Respondents had the most faith in NGOs, but ratings agencies such as FTSE4Good, and Bloomberg came a close second – well above governments, journalists and consumers. But trust is not strong. When asked about the credibility of ratings, none scored higher than 16%. Nearly all respondents (94%) believed that the objectivity and credibility of data sources is critical to how much they trust a rating.

In a brief review of 30 private certification schemes, in common with the academic literature discussed in section 4.2 above, it was found that the schemes deployed a large number of indicators, on average 120 covering particularly the economic and environmental aspects of sustainability. The procedure for all these schemes consisted of an initial self-assessment by the farmer/manager/land owner, followed by independent third-party review. There were few signs that the indicators chosen were based on the official indicator sets of the EU. The general approach was mostly to ensure farms achieved minimum standards. They are generally not designed to measure change over time on a continuous scale, nor to provoke further improvement once minimum standards are attained. Two exceptions to this are BASF's AgBalance scheme, which employs continuous indicators aimed at supporting and spurring improved environmental performance over time (BASF 2010), and Syngenta's Good Growth Plan, which takes a similar approach (Syngenta 2013).

The critical evidence to judge if commercial certification and sustainability schemes could have a constructive role to help EU agriculture to a sustainable intensification path, is whether they have made any noticeable difference to any aspects of sustainability. This would require some monitoring of farms enrolled in such schemes. Ideally this would test if the performance of participants on aspects of sustainability that the scheme was designed to improve were any different to that of farms not in such schemes. Unfortunately no studies doing this were found. There is a reluctance of commercial companies to survey the participants on their schemes for a fear that it would change the nature of the commercial relationship. But the absence

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of such information makes it difficult to claim that these schemes have any impact at all on sustainability. It is suggested that this is an issue which merits more attention.

Because these schemes have wide coverage, and are independent of public finance, there could be scope to utilise this route to achieve real improvement in farm sustainability. There should be a presumption that these schemes are more than simply lip service to corporate social responsibility. If parts of agriculture – especially those parts which make heavy use of the potentially damaging agricultural inputs – are considered to be at risk of approaching environmental thresholds then it is in the private interests of the farmers concerned and their suppliers to address such challenges, quite apart from the more general public interest. A number of aspects of these private sustainability schemes merit some tightening up to enable this approach to make a more meaningful contribution towards sustainable intensification. First it would be helpful to narrow the definition of 'sustainability' to elements that are quantifiable and crucial to the farming operation's ability to continue indefinitely, preferably relating to official environmental indicators. Second, it is preferable to measure performance against indicators on a continuum rather than pass/fail some minimum standard. Third, these approaches would achieve greater public trust and respect if there were some open and transparent monitoring of progress of the performance of participants in the scheme towards aspects of environmental and economic performance.

Drawing the threads of this chapter together.

This report has argued that it is the sustainability aspect of sustainable intensification which requires most attention in the European Union. It has been further argued that within the broad concept of sustainability, the environmental dimension requires more attention than the other pillars. The collective action required to define and measure the environmental performance of agriculture is well advanced, although not complete. However, enough data already exists to pinpoint where biodiversity, soil, water, climate and landscape management are not adequate to achieve the standards set in EU legislation. This is well exemplified in the first case study which follows. Equally, the suite of policies to protect the farmed environment through environmental directives and agricultural policy instruments is well developed. In short, in Europe we know what the problems are and where they are, and we have policy measures which could contribute to dealing with them, so why is progress to reducing these problems insufficient?

One answer is a misguided concern of the contribution of European agricultural production to global food security. The worry is that by taking measures to improve environmental performance this will reduce production potential in a world of still growing population and food demand. These fears are exaggerated. Europe is a relatively high cost production area and its agricultural exports are of more processed high quality foods and highly developed plant and animal genetics. It is therefore not generally a source of low cost calories for poorest countries. Second, Wang et al (2012) conclude their detailed analysis of total factor productivity growth that Europe's output growth has indeed slowed over several decades but this slowdown in "is entirely due to withdrawals of resources from agriculture especially labour, and not to a slowdown in productivity growth". They point to the continuing long-term trend in underlying productivity growth which, in turn, does respond positively to R&D effort. In this context the potential output loss from the further withdrawal of a few percentage points in land to provide biodiversity and water protection could be replaced by less than half a decade's productivity growth. Third, such is the size of food waste in the EU, that the private and public efforts to reduce this could also 'replace' output forgone from some production areas where actions are taken to reduce negative environmental effects of intensive production.

Another answer lies perhaps with the perceptions and motivations of farmers. It is not at all clear that they appreciate the extent of the environmental degradation that has accumulated over the last century, or the potential threat this poses for continued future production. This underlines the importance of continuing the efforts to provide the evidence of this damage, and to put more effort to investigate whether there are environmental thresholds being approached.

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6 Three case studies

Three case studies were devised to supplement and illustrate the general analysis of sustainable intensification developed in the above first five chapters. They were chosen to deal with quite different issues, soils, nutrients and biodiversity and they employ different analytical approaches.

The first, under the direction of Prof Blum of BOKU Vienna, focuses on soil performance and resilience. This builds on, and tries to give practical expression to, the ideas discussed in sections 5.1.1 and 5.2.3 that managing agriculture towards a development path of sustainable intensification is highly dependent on having sound measurement of the underlying conditions.

The second case study, under the direction of Prof Heissenhuber of Technical University Munich, is concerned with nutrient management. This deals with a well-acknowledged problem of European intensive livestock production that it is associated with a chronic problem of nutrient surplus, principally nitrogen and phosphorus, on agricultural soils. This case study probes some alternative ways of dealing with this regional imbalance of nutrients. It tries to do so by starting from the broad perspective, which juxtaposes the nutrient excess intensive livestock and urban areas with the nutrient deficit cropping areas. In this perspective it makes sense to consider how the excess nutrients can be recovered from the surplus regions (animal manure and sewage sludge) and recycled to the deficit regions. This case study offers some preliminary calculations to illustrate the kinds of analysis which can shed light on this question. The ultimate aim is a more efficient use of nutrient in EU agriculture by reducing the nutrient leakage to water and atmosphere, and at the same time recycling organic mate back to soil, reducing fossil fuel use and contributing renewable energy production. This offers a different perspective on actions which can be seen as quite consistent with the proposed definition of sustainable intensification.

The third case study, also directed by Prof Heissenhuber, focuses on ways of looking at biodiversity and how it can be better managed in farming areas. This study considers the extent to which biodiversity and agricultural productivity have to be traded-off against each other or whether there are sustainable intensification pathways which offer opportunities to improve both together. The study gives particular emphasis to spatial-temporal considerations in defining the appropriate conservation measures for biodiversity, and how these will be heavily conditioned by the presence or absence of structural elements, e.g. hedges, trees and water-courses, in the rural landscape.

6.1 European land quality as a foundation for the sustainable intensification of agriculture[31]

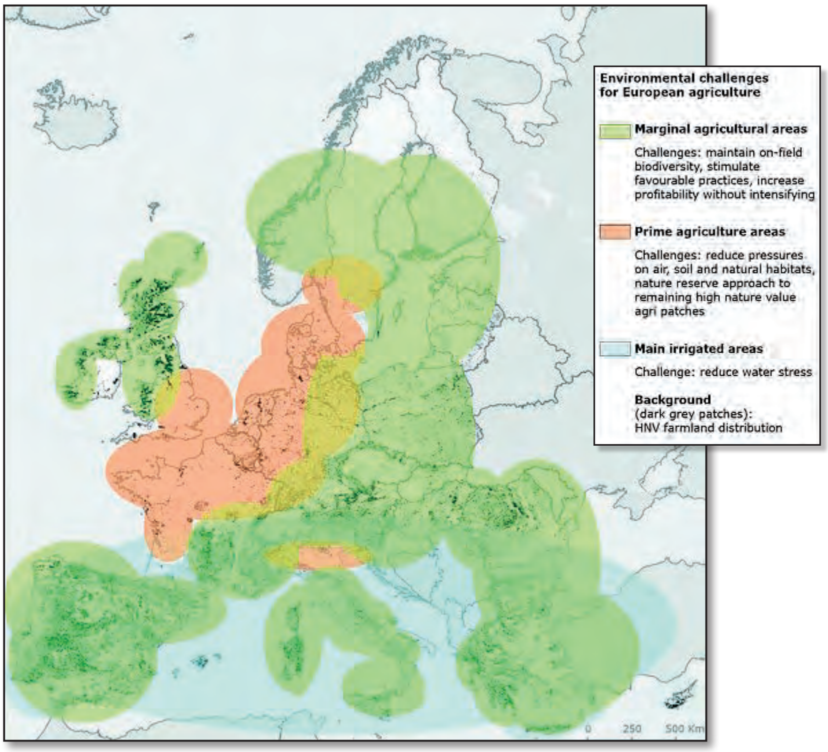
Introduction

Soils perform a variety of environmental, social and economic functions (Blum 2005). These include: 1) biomass production for different uses; 2) buffering, filtering, biochemical transformation; 3) acting as a gene reservoir; 4) the physical basis for human infrastructure; 5) a source of raw materials and; 6) geogenic and cultural heritage.

Soil degradation affects our capacity to produce food, prevent droughts and flooding, control biodiversity loss, and tackle climate change (Jones et al. 2012). Therefore, if the intensification of agriculture in Europe is to be sustainable, it is essential that it does not continue to degrade our soils. Sustainable land use has to harmonize the use of the six listed soil functions in space and time, and minimise uses which cannot be reversed within 100 years or 4 human generations (e.g. sealing, excavation, sedimentation, severe acidification, contamination or pollution, and salinisation). In the context of this study, we only consider the three ecological functions: biomass production; filter, buffer and transformation processes and gene reserve (biodiversity).

To evaluate the potential of soils in Europe to withstand further intensification, this study brings together the concepts of resilience (the capacity of systems to return to (a new) equilibrium after disturbance) and performance (the capacity of systems to produce over long periods). By bringing together soil data that indicates the resilience and performance of the different soils, this study enables us to better understand which soils in Europe could have the potential for SI and where environmental risks of more intensive agriculture are too high and therefore extensification should be applied.

Figure 6: *Indicative map of combined environmental challenges related to land use*



Source: European Environmental Agency, 2013[32]

No one single indicator can be used to cover all aspects that define the capacity of soil systems to provide the above mentioned goods and services and nor would it be feasible (or necessary) to analyse all possible influencing indicators (Kibblewhite et al., 2008). Therefore, the indicators chosen for this report are those that are comprehensive enough to characterise the intrinsic potential of soils to level out or reduce negative impacts of agricultural intensification based on available literature.

An important factor concerning the ability to intensify agriculture sustainably is soil organic carbon which is the basis of soil biology and influences most soil properties, including the filter, buffer, transformation, and water holding capacity. Soil organic matter is defined as all dead material in or on the soil, such as plant or animal material including leaf litter, woody debris and dead roots (Sollins et al. 1996). Organic carbon is also a source of energy for microbial activities and provides better nutrient availability, bulk density and cation exchange capacity (CEC), which are intrinsically important factors for high resilience and performance. CEC and pH determine the mobility of nutrients and their availability for plants. Soils

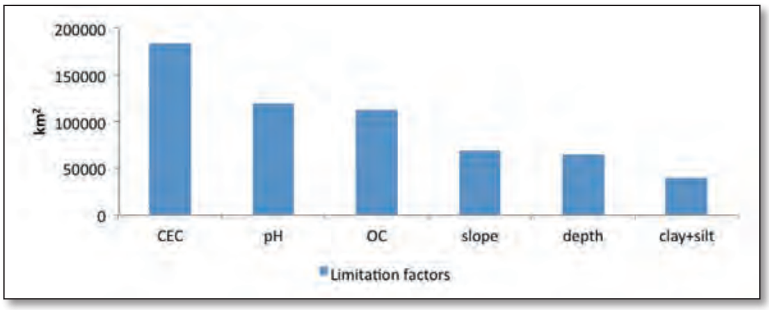
31 This case study was written by Winfried E.H. Blum, Jasmin Schiefer and Georg J. Lair University of Natural Resources and Life Sciences (BOKU) Vienna, Austria. The authors would like to thank Luca Montanarella, Gergely Tóth and Tamás Hermann from the IES/JRC, Ispra, Italy, members of the Catch-C project (especially Heide Spiegel) and the Federal Institute for Geosciences and Natural Resources in Germany for support with soil data and further information.

32 The European Environmental Agency (EEA 2013) summarised the complexity of multiple demands and environmental challenges on land and soil resources, including agricultural intensification, land abandonment and urban sprawl, and its pressures on biodiversity and water resources (Figure 6).

with low pH and reduced microbial activity show an increase of solubility and mobility of metals, facilitating the contamination of groundwater. To choose soils with these parameters can help reduce environmentally adverse impacts through agricultural production and positively influence biodiversity and the delivery of goods and services provided by soil. For example, deep soils with high clay and silt contents are better able to retain nutrients and thereby reduce the contamination of groundwater through nutrient runoff. These soils also have a better water retention capacity and can therefore compensate during periods of drought.

The most frequent limiting factor for sustainable intensification is the cation exchange capacity (CEC) which is the capacity of the soil to retain inorganic and organic compounds in the soil body, thus protecting the groundwater of the food chain against contamination. This capacity is also strongly dependent on pH value, soil organic matter and clay minerals. Soil pH and organic carbon (OC) cause similar limitations in many areas. The clay+silt content is the least minimising factor for SI in Europe (Figure 7).

Figure 7: *Areas of arable land subject to six limiting factors in Europe (in km²)*



Material and Methods

The comparison of soil monitoring data in Europe is quite difficult because of a lack of uniformity in the scope of monitoring and methodological approaches. Some countries have a dense geographic coverage of soil monitoring data (e.g. England and Wales, Northern Ireland, Austria, Denmark, Malta), whereas others have fewer monitored sites (Spain, Italy, Greece) (Morvan et al. 2008). Therefore we used data from the Land Use/Land Cover Area Frame Survey 2009 (LUCAS) provided by the Institute for Environment and Sustainability of the European Commission Joint Research Council (IES/JRC), which was carried out in 23 Member States (Malta and Cyprus were subsequently included) and provided soil data from ~20 000 geo-referenced sites which were all analysed in one central laboratory (Toth et al.,2013). LUCAS soil samples were taken in such a way that the land use and topography of each country up to 1,000 m elevation was included (Ibid.). The density of the sample points is around 1 per 199 km², corresponding to a grid cell size of ~14 km x14 km (Panagos et al. 2013) and includes topsoil data (0-20 cm depth).

The study is based on the theory that fertile soils with specific characteristics have a high resilience against physical, chemical and biological disturbances and also show a high performance capable of supporting the widest range of agricultural commodities if managed safely. Therefore, 6 specific land and soil characteristics were chosen, based on available literature and expert knowledge, these are shown in Table 1.

Table 8: *Indicators and threshold levels for Sustainable Intensification*

	excellent	good	medium	poor	unit
SOC %	>4	2-4	1-2	< 1	%
Clay+ Silt	>50	35-50	15-35	<15	%
pH		6.5-8	5.5-6.5	<5.5; >8	in H2O
CEC		>25	10-25	<10	cmol/kg
Depth*		>60	30-60	<30	cm
Slope**		<8	8-15	15-25	%

** Estimated according to WRB 2006*
*** Sites with slopes >25% were excluded from calculations*

Each soil analysed was scored for each of the six indicators as follows: poor (1), medium (2), good (3) and excellent (4). The indicators were taken from LUCAS topsoil survey for SOC, clay+silt, pH and CEC, and from the European Soil Data Base, ESDB, for slope and depth. The scores for the depth of the soil were estimated according to the soil type description from WRB 2006 (Table 8). Soils on slopes steeper than 25% were excluded because of the risk of erosion and thereby irreversible soil loss.

In combining the scores for the six soil factors to define four overall classes of land suitable for sustainable intensification higher weights were given to the % of Soil Organic Carbon (SOC) in the soil, and clay+silt. This was done to reflect the importance of these factors on soil resilience and performance.

In this way, the definition of suitability for SI is based on intrinsic soil quality parameters such as 'resilience' against adverse ecological impact and 'performance' in the sense of productivity (Table 9).

Table 9: *Soil types and score of its depth estimated from WRB 2006 soil description*

Soil type	Score of depth	Soil type	Score of depth
Histosols	3	Stagnosols	-
Anthrosols	-	Chernozems	2
Technosols	-	Kastanozems	2
Cryosols	-	Phaeozems	2
Leptosols	1	Gypsisols	2
Vertisols	3	Durisols	-
Fluvisols	2	Calcisols	2
Solonetz	3	Albeluvisols	2
Solonchaks	3	Alisols	3
Gleysols	2	Acrisols	3
Andosols	2	Luvisols	3
Podzols	2	Lixisols	2
Plinthosols	3	Umbrisols	2
Nitisols	3	Arenosols	2
Ferrasols	3	Cambisols	2
Planosols	2	Regosols	1

1= <30cm depth; 2= 30- 60 depth; 3= >60cm depth

Our analyses were done with ArcGIS 10.2[33] using LUCAS topsoil surveys data, the European Soil Data Base (ESDB) 2.0 1:1,000,000 (provided by IES/JRC European Commission) and the Corine Land Cover 2006 (CLC 2006) map.

As a last step the map of non-irrigated and permanently irrigated arable land from Corine Land use Cover (CLC 2006) was analysed to exclude sites which are not under agricultural cropping. Data is not yet available for all arable land in Europe therefore not all sites could be included in this study.

The scores from all the indicators were added together for a total score before being categorised into four different classes in terms of sustainable intensification potential based on literature data and expert judgment.

1 (--): no intensification possible –extensification suggested;
2 (-): in general good conditions but at least one indicator out of range – not suitable for SI;
3 (~): SI only possibly with restrictions;
4 (+): land suitable for SI.

The sites with a score between 6 (when all parameters were scored with 1) and 10 are classified as class 1 (--). This means that the soil has intrinsic soil properties which cannot support any form of environmentally friendly intensification and therefore extensification has been suggested.

The sites with a score of >10 are classified as class 2 (-) sites. This means that the soil is in good or medium condition but one or even more indicators are in a poor condition and therefore intensification is only possible with high risk.

A total score of 11 to 15 represents the medium class 3 (~) indicating a poor potential for SI i.e. that intensification should only be done with great caution.

Finally, sites which can classed as suitable for SI (class 4 (+)) are soils which can better compensate environmental impacts due to agricultural production. This land is suitable for intensive agriculture with the important qualification that it is managed in a sustainable way.

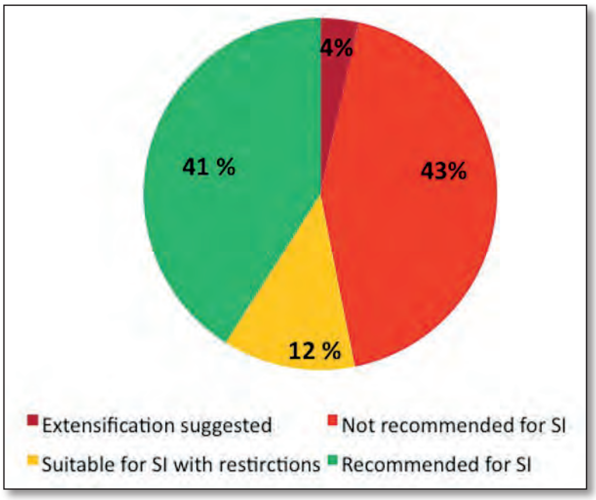
It is very important to note that this classification of land suitable for sustainable intensification *only* relates to the suitability of the soil. Management decisions to intensify must, of course, take into account the full range of other environmental considerations and specific local factors, including, impacts on and availability of water, GHG emissions, biodiversity and landscape.

Results

A total area of 671,672 km^2 of arable land in EU-25 (excluding Romania, Bulgaria and Croatia) was analysed. This is about two-thirds of the EU-25 arable area (915,430 km^2). The results showed that almost half of this area (45%) is not suitable for sustainable intensification, of which almost 4% has such low intrinsic qualities that it is categorized as class 1. It is further suggested that on land classified as class 1, a reduction of land use intensity including a possible conversion into grassland should be considered to reduce environmental harm. 12 % of the area is categorised as class 3, meaning that sustainable intensification on these soils is not recommended in their present state and therefore these soils should be used with caution. Finally, intensification is possible on 41% of the analysed soils because they have a high resilience against adverse impacts from intensive agricultural production (Figure 2) and show a high performance. On such land intensification carries less environmental risks regarding the contamination of groundwater resources and of the food chain through the use of fertilizers and plant protection compounds.

[33] ArcGIS is a common geographic information system developed by ESRI. It is used for creating, managing and analysing maps and geographic information data.

Figure 8: Soils and their suitability (in %) to be used for sustainable intensification on arable sites of 25 EU Member States (excluding Croatia, Bulgaria and Romania).



The classification of soils according to their suitability to support intensive agriculture can usefully be shown in maps. Figure 4 shows the Po basin (Lombardy) in Northern Italy. Most soil resources in this region are suitable for intensive agriculture, and indeed most are already farmed in this way. The region around the Po river basin has a high potential similar to many other river basins in Europe. Figure 8 also shows low and high potentials (red and green areas) can be situated in close proximity indicating that soils are highly heterogeneous emphasising that management decisions about appropriate intensity can only be taken at a local scale.

Two other examples are those of Southern England (GB); (Figure 5) and the Vistula River Estuarine in Poland (Figure 6).

Figure 9: Land suitability for SI in the Po basin (Lombardy), Northern Italy

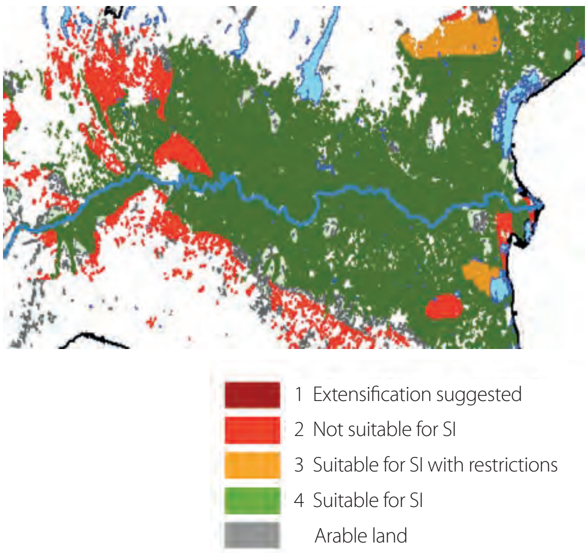


Figure 10: Land suitability for SI in Southern England (GB)

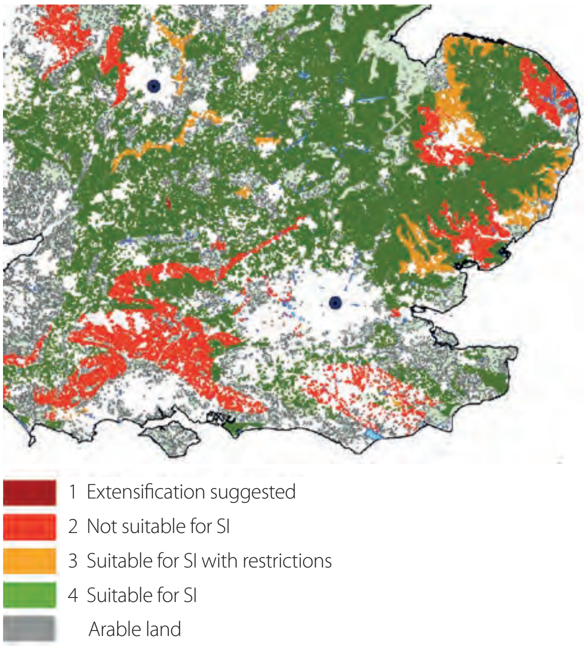


Figure 11: Land suitability for SI around the Vistula River Estuarine

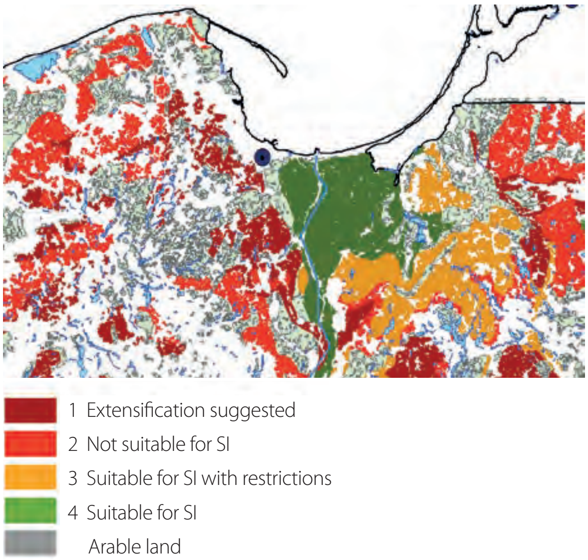


Table 10 summarises the distribution between the four SI classes by Member States. The countries with the highest proportion of land most suitable for intensification are Belgium, Slovakia, the United Kingdom, Latvia, the Netherlands and Hungary. The countries with the smallest proportions of arable land suitable for intensification are Cyprus Malta, Poland Portugal, Spain and Greece.

Table 10 shows that not all arable land has yet been analysed (see column on the right). Therefore these distributions will change as the full data becomes available (especially Cyprus). Although Malta is apparently 100% analysed, although this result is not reliable as it is based on a single sample plot from the LUCAS topsoil survey. .

Table 10: *Distribution of land between SI classes for 25 EU Member States*

	Extensification suggested (%)	Not recommended for SI (%)	Recommended with restrictions (%)	Recommended for SI (%)	Analysed arable land (km2)*	% of arable land**
Austria	0	19.7	25.1	55.2	7872.3	71.6
Belgium	0	7.0	0.1	92.9	3793.8	56.5
Cyprus	9.7	90.3	0.0	0.0	693.4	26.5
Czech Republic	1.3	26.9	23.9	47.9	23856.4	73.2
Denmark	1.3	50.5	21.1	27.1	22048.6	79.9
Estonia	0.5	34.5	0.1	64.9	3822.8	58.0
Finland	0.2	28.7	6.1	65.0	12658.6	79.2
France	0.5	43.4	5.4	50.7	113658.6	74.0
Germany	1.6	44.3	15.4	38.7	87885.6	64.4
Greece	3.4	69.4	3.5	23.7	16903.3	77.4
Hungary	1.8	18.4	14.5	65.3	40855.3	82.5
Ireland	0.0	12.0	31.5	56.5	2986.1	55.4
Italy	1.0	39.4	8.7	50.9	69563.0	83.8
Latvia	0.0	19.1	9.6	71.3	6370.0	69.9
Lithuania	2.5	27.3	8.4	61.9	12757.2	57.5
Luxembourg	0.0	0.0	0.0	100.0	2.5	1.1
Malta	100.0	0.0	0.0	0.0	1.2	100.0
Netherlands	0.0	24.6	4.2	71.1	5700.7	75.1
Poland	16.7	59.1	16.7	7.5	91742.9	65.8
Portugal	12.9	56.6	17.6	12.9	8846.7	66.1
Slovakia	0.1	6.6	16.9	76.3	13441.7	80.6
Slovenia	0.0	56.7	13.8	29.5	505.5	44.9
Spain	2.9	69.1	14.1	13.8	98607.6	80.3
Sweden	1.1	42.1	8.9	47.9	27067.3	90.7
United Kingdom	0.0	18.9	8.2	72.9	45171.7	84.6

** Because all surfaces according to Corine Land Cover 2006 are used as arable land the recommendation for extensification also includes the change from arable land to grassland.*
*** According to analysed data from Corine Land Cover 2006*

Interpretation and discussion

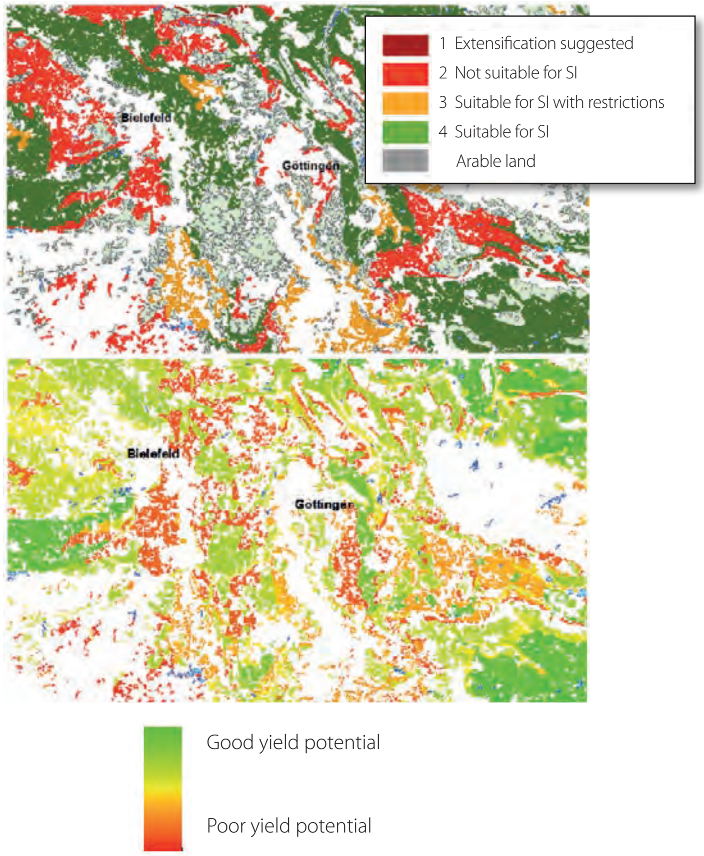
The analysis of land recommended for SI shows that many regions with the highest resilience and performance are in prime agricultural regions that are already facing some of the strongest environmental pressures (Figure 3). For example, the intensively cultivated production area in the Lombardy is one of the most intensively irrigated regions in the EU with widespread conventional tillage (Sánchez et al. 2013), and a nitrogen surplus at field scale ranging up to 339 kg N ha^{-1} due to the high usage of fertiliser. Whilst the Lombardy region is suitable for intensive agriculture, this does not mean that further intensification which adds to environmental damage could be undertaken. Decisions about intensification must be taken at a local scale, and take into consideration: soil homogeneity, climatic conditions, the use of machinery and the likely environmental effects. A helpful tool to support decision making at a local level could be the results of projects like the Catch-C project (EU, FP7, Grant Agreement N° 289782) which collected information on current farm management and assessed the results of biophysical impacts of management from a large set of current field experiments all over Europe (Catch-C, s.a.).

The best management practices minimise soil disturbance while at the same time enhancing plant establishment on the soil surface: the plant is the best soil conservation element (Guzmán et al. 2014). The preliminary results of the Catch-C project showed that, based on their indicators of sustainability, the best management practices for European conditions are generally the use of farmyard manure (FYM) and compost application, crop rotation and non-inversion tillage (Spiegel et al., 2014). The physical quality of soil in agricultural sites shows large differences between different climatic zones in Europe due to differing water availability (Guzmán et al. 2014), with the production capacity of Mediterranean soils being one of the most limited.

Our study assumes that agricultural soils with high resilience and performance also have the highest yield potential. As noted in the methodology, this assumption was tested by comparing our results with the agricultural yield potential of German soils according to the Müncheberg Soil Quality Rating (SQR). The SQR shows the potentials, risks and crop yields estimated for soils on a large scale. The German soil map 1:1,000,000 (BÜK 1000) was evaluated on the basis of 8 indicators which were scored (good, medium or poor), weighted and summarised as well as 4 main hazard indicators (soil depth to hard rock, high percentage of coarse texture fragments, acidification and drought risk); (Richter et al., 2009).

A comparison of both results shows that land which is not suitable for SI (class 1+2, SI) differs by only 4% from land with poor crop yield potential (class 1+2+3, SQR). Good soil conditions (class 3+4, SI, and class 4+5, SQR) also match very well in both analyses. It was also revealed that soils with the highest yield potentials are always congruent with land recommended for SI (class 4, SI). However, land delineated for SI also contains some soils with a lower yield potential class (class 4, SQR). This difference is explained as the classifications were based on different criteria. The similar accuracy and similar results for "good" and "poor" soils indicate, that our six most important factors chosen for the SI concept provide a clear picture of the land potential for an environmentally friendly intensive agriculture, but also for defining areas where high yields and less hazards in general can be expected.

Figure 12: *Comparison of the potential for Sustainable Intensification (A) and the agricultural yield potential according to SQR (B) of soils western of the Harz region (Germany)*



Conclusions

The conclusion of this study is that 41% of the arable land in Europe could be suitable for sustainable intensification. However, most of these sites are already intensively used and are already subject to intensive environmental pressures. As land and soil are heterogeneous natural resources, any decision with regards to the intensification *must* take local conditions into consideration.

The new member states in the EU like Bulgaria, Croatia and Rumania, are assumed to have high potential for intensification due to the current less-intensive farming systems, but these countries have not yet been analyzed and LUCAS data is not yet available.

6.2 Nutrient management [34]

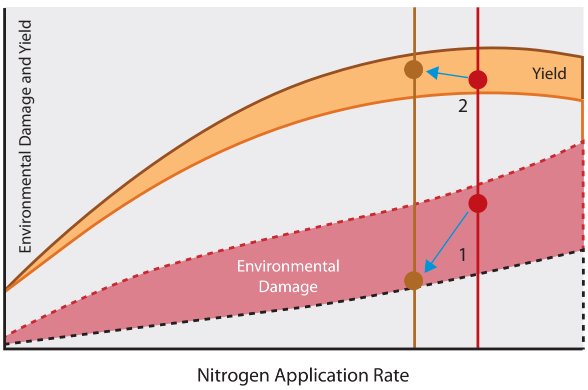
Introduction

In the future there will be an increasing need for agricultural products, because of a growing world population, rising incomes with increased meat consumption, and expanding agro-fuel production. This additional demand can be met by clearing forests or intensification of agricultural production. Given the important functions of forests it is preferable to increase the output per hectare of agricultural land, provided it is done without endangering the satisfaction of the needs of future generations.

Intensive agriculture is characterized by a high use of resources such as labour and capital. High production per hectare requires a high amount of nutrients, particularly nitrogen, phosphorus and potassium. The application of these fertilisers causes problems for the environment in the form of eutrophication of groundwater and surface water. Also the manufacture of nitrogen fertilizer is energy intense (Filson, 2005a). In a closed nutrient cycle there would be no need for artificial input of fertilizer.

Fig. 1 shows typical production relationships for fertilizer application, in which yields rise with fertilizer input to a point (the green area) and environmental damage (orange) also increases with fertilizer use (the orange area).

Figure 13: *Ideal sustainable Intensification moving to higher yield - lower damage*



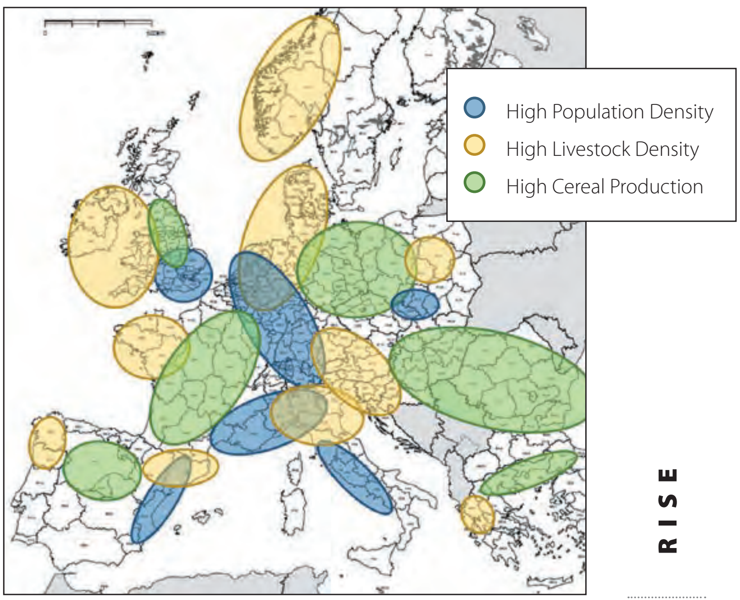
Existing, not very productive, and environmentally damaging technology and practice might be represented by the lower boundary of the green area and the upper boundary of the orange area. The aim of sustainable intensification is, through the application of best practices in resource efficiency, to shift the yield curve upwards towards the boundary of the green area and the environmental damage towards the lower boundary of the orange area. Thus if a business could shift from the red to the green points it would be raising its food productivity whilst reducing the environmental damage.

The development of modern agriculture in an urbanised society has been characterised by a strong move towards specialisation. Three types of region can be identified which characterise the nutrient flows inherent in current production systems:

- Specialised crop regions mostly without livestock export food and feed. In doing so these regions export nutrients contained within their products, and have to import plant nutrients for their crops.
- Specialised livestock regions which import most of their animal feed, export food to urban areas and simultaneously produce an excess of nutrients, mostly in the form of manure.
- The urbanised regions have large imports of crop and livestock products, and a great excess of nutrients which occur in wastewater and sewage sludge. These are regarded as a substantial waste management challenge.

This separation of functions shown in Figure 14, offers advantages of economies of scale in crop and especially livestock production, but it also results in negative local impacts of surplus nutrients in livestock regions and nutrient deficits in arable regions.

Figure 14: *Regional concentration of cereal production, livestock and human population*



[34] This case study was prepared by Alois Heißenhuber and Peter Schießl, Agricultural Production and Resource Economics, Technische Universität München-Weihenstephan, Alte Akademie 14, D-85350, Freising-Weihenstephan.
The findings presented below partly originate from on currently ongoing project financed by the German Federal Environment Agency (UBA) titled "Schließen von landwirtschaftlichen Nährstoffkreisläufen durch einen überregionalen Wirtschaftsdüngeraustausch" (Project No. 37240).

This in turn means large-scale transportation of food and feed products between regions. It also sets a large challenge to try and recover nutrients from organic fertilizers (e.g. manure) and also from human waste so they may be processed and returned to the arable regions (Scaglia, D'Imporanzo, Garuti, Negri, & Adani, 2014).

Nutrients are strongly diluted through the process of livestock production. Animal manure and slurry have high water contents. The concentration of nitrogen and phosphate in human sewage sludge is also low. As a result the transportation of waste is expensive. Therefore, reducing the water content in manure and sewage sludge by appropriate treatments could reduce transport costs for long distance transport.

There could be several environmental benefits if nutrient use efficiency were increased. This could reduce nutrient leaching to groundwater and surface water and consequent eutrophication of water bodies, there could also be reduced greenhouse gas emissions, from inefficient livestock production and transportation. Returning waste materials back to the soil can also help soil organic matter. Two strategies to help increase nutrient use efficiency are:

(a) Nutrient recycling

(b) Coupling of livestock farming to areas

To implement the recycling of nutrients, problems of transporting manure need to be solved, the negative characteristics of manure, waste water and sewage sludge reduced, and the nutrients provided in the desired form. There are a number of technical approaches for waste processing, many f these involve some anaerobic digestion of the waste materials, resulting in some liberation of energy, and resulting in digestate which has higher nutrient concentration and valuable organic material to be returned to the soil. Table 11 shows some illustrative costs involved for two broad approaches.

To the extent that mixed livestock and crop farming can be created this could decrease the density of livestock, and therefore reduce public pressures caused by large scale livestock farming and it could mean much lower transport costs for organic fertilizer. However, such reduction in specialization may also reduce the economies of scale in livestock production.

This case study has tried to assemble the kind of data required to understand the relative costs and benefits of recovering nutrients and transporting them to crop production areas versus reducing the scale and concentration of livestock production In order to reduce the local nutrient surpluses.

- Nutrient recycling from organic substrate and transport costs
- Comparison of economies of scale with transport costs for dairy farming

Treatment and transport options and costs.

The recycling of organic substrates and nutrients, particularly human and animal waste, requires several technical challenges to be overcome.

- Sanitary features
- Odor impact
- Fertilizing properties
- Impacts on soil, air and water

Thermophilic anaerobic digestion can help to deal with all of these issues (Scaglia, D'Imporanzo, Garuti, Negri, & Adani, 2014). Digestion of this material at a temperature of 55 °C or higher and digestion time of more than one month will ensure a safe sanitary status of the digestate. Techniques are also available to reduce odor impact. The nutrient value of the digestate depends on the process, the form of digestate and the time of application (Gutser, Ebertseder, Weber, Schraml, & Schmidhalter, 2005).

Table 11: *Methods for treatment of manure and sewage sludge (Döhler & Wulf, 2009)*

	Partial methods				Full method
€/t Digestate	**Separation**	**Drying**	**Evaporation**	**Stripping**	**Membrane process**
Fixed costs	2,15	4,01	3,03	5,07	5,19
Energy costs	0,30	3,74	7,03	3,42	2,77
Application	4,77	4,53	2,82	2,21	3,17
Gross costs	**7,23**	**12,28**	**9,88**	**10,70**	**11,13**
Nutrients	-4,40	-4,26	-4,40	-4,38	-4,40
Bonus for heat use		-1,23	-2,15	-0,88	
Net costs	**2,82**	**6,80**	**6,32**	**5,43**	**6,72**

Transportation costs will depend heavily on the technology applied and hence the concentration of the nutrients. Processing costs and the resulting digestate properties depend on the treatment. The baseline approach is digestate transportation without treatment.

The first treatment option is separation by screw presses. Here the material is separated into liquid and solid fractions, 13% of the digestate is in solid fraction, the rest remains as liquid. This treatment costs 0.54 €/m³ digestate. The nitrogen separation achieved is 30% solids to 70% liquid. A second treatment process is to use ultra-filtration. From which 16% of digestate remain in the solid fraction, 38% in the liquid fraction and 46% of total weight is water and can be discharged into preflooder. This costs 6.05 €/m³. Table 12 summarises these figures.

Table 12: *Treatment options for digestate*

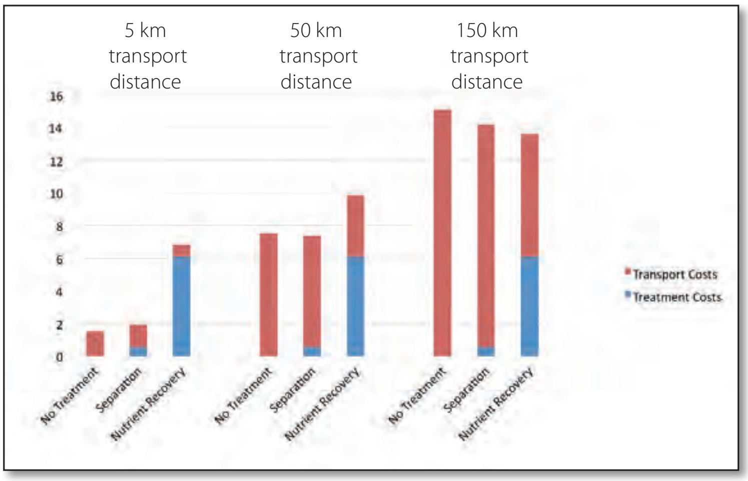
	No treatment	Separation	Separation and ultra-filtration
Costs per m³ digestate	0 €/m³	0,54 €/m³	6,05 €/m³
Solid fraction per m³	0 %	13 %	16 %
Liquid fraction per m³	100 %	87 %	38 %
Water pre-flooder quality	0 %	0 %	46 %
Nitrogen rate solid – liquid	0:1	0.3:0.7	0.27:0.73

The total costs for applying digestate on agricultural land consist of treatment costs, transport costs and application costs. Application costs remain the same for all treatment options, so is not considered further.

The data sources for treatment costs are KTBL (2013) and Döhler and Wulf (2009). Transport costs are calculated according to technical planning data (KTBL, Betriebsmanagement - Datensammlung 2012/13, 2013). For separated digestate it is assumed that the need for transportation is reduced by 9.2% because of nitrogen accumulation in solid fraction and cheaper transport per kg nitrogen over high distances. For ultra-filtration this effect reduces transportation weight by 46% because of the reduced water content and 1.8% because of the higher nitrogen concentration in the liquid fraction. There could be additional effects because of the improved fertilizer property but these have not been considered.

Figure 3 shows transport and treatment costs for three transportation distances and for the three treatment procedures.

Figure 15: *Best manure treatment procedure subject to distance*



For a short distance, the transport and treatment costs for a full digestate processing method is more than three times higher than the other two options.

For medium transport distance (50 km) separation is slightly cheaper than no treatment, and 25% cheaper than ultra-filtration. It is only for the long-distance transport, over 90 km on average, that full processing via ultra-filtration is the most cost-effective way of treating digestate to transport nutrients back to arable regions.

Economies of scale vs. Transport costs

An alternative approach is to consider changing the balance between livestock and crops within a locality so that the manure can be spread directly on the crops without treatment and specialised road transport. This approach may mean that livestock production has to be downsized to reduce the local nutrient surplus. This may in turn mean that cost reductions due to economies of scale in livestock production are lost. This section tries to quantify this trade-off between lost scale economies at far level versus less transport cost.

The observation of single-farm effects of transportation costs and herd size can provide useful farm management information. This will not be sufficient to assess regional economies of scale but it can give some useful insights.

To answer the question if it is better to transport manure or to reduce livestock densities we must estimate how costs decrease with scale of livestock production. Table 3 shows some data on the cost reduction effects of successively larger dairy farms as measured by number of cows, (KTBL, Betriebsmanagement - Datensammlung 2012/13, 2013). For herd sizes greater than 500 cows the degression is estimated by an exploration of the rate of reduction of fixed costs.

Table 13: *Reduction of fixed costs by size of herd in dairy farming*

Places	64	120	246	492	984	1968
Fixed Costs [€/Place*Year]	1244	907	789	736	711	700
Degression [€/add.Place]		6,01	0,93	0,22	0,05	0,01

Table 14 summarises the other technical information in the analysis, that is, assumptions about manure production and composition, and fodder.

Table 14: *Manure production and nutrient contents*

	Dairy cow	**Reference**
Manure [m³/Place*Year]	26,9 m³	(LfL, Leitfaden für die Düngung von Acker- und Grünland, 2012)
Nitrogen [kg/Place*Year]	118 kg	(DüV, 2012)
P2O5 [kg/Place*Year]	39,14 kg	(LfL, Leitfaden für die Düngung von Acker- und Grünland, 2012)
K2O [kg/Place*Year]	132,8 kg	(LfL, Leitfaden für die Düngung von Acker- und Grünland, 2012)
Fodder [t/Place*Year]	3,37 t	(KTBL, Betriebsplanung Landwirtschaft 2012/13, 2012)

For a typical single farm analysis further assumptions have to be made about the area of arable land reachable from the diary farm to calculate transport costs. To illustrate, an area with 40% arable land reachable within a given transport distance is chosen. For nutrient occurring on the farm there is a certain percentage of arable land available for the farm. For the scenario 'low transport distance' 5 % of arable land is available for the farm. For the scenario 'high transport distance' 0.5 % of arable land is available for applying nitrogen amount according to the nitrogen application limit. Thus the transportation distance is calculated according to the following formula (low transport distance):

$$TR(km) = \sqrt{\frac{AC(ha)}{40\,\% * 5\,\% * 100\frac{ha}{km^2} * \pi * 1{,}41}}$$

TR(km) stands for the transport distance, AC(ha) is the area of land (ha) needed for manure application in order to fulfill the good agricultural practice and respect the limit of 170 kg N/ha. It is assumed that 40 % of total area can be reached as farmland within this distance where 5 % of this farmland is available at the best scenario '5 %'.

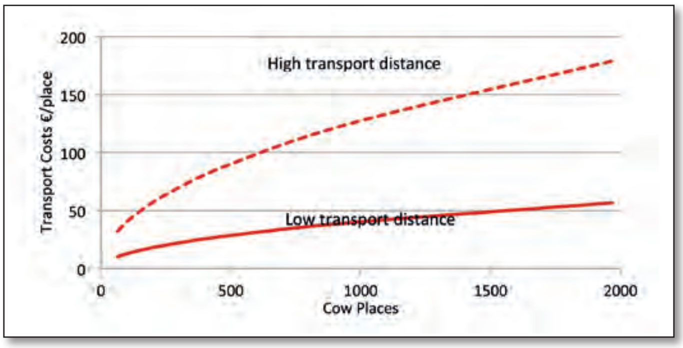
Table 15 shows the average transport distance for different dairy herd sizes and availability of farmland for manure application. Herd size is 64, 120, 246, 492, 984 and 1968, where farmland availability is 5 % and 0.5 % of total farmland.

Table 15: *Farmland required and distance for transportation – dairy farming*

Cows	64	120	246	492	984	1968
Required ha 170 kg N	44	83	171	342	683	1366
Transport [km] 5%	2,2	3,1	4,4	6,2	8,8	12,4
Transport [km] 0,5%	7,1	9,8	14,1	19,9	28,12	39,8

The results of the calculation of transport costs for dairy farming are shown in Figure 16. Transport costs for high and low transport distances per cow place are plotted in this chart.

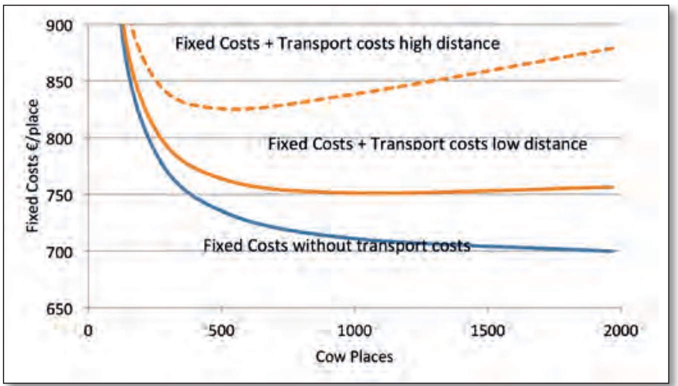
Figure 16: *Transport costs as a function of land availability and herd size – dairy farming*



The transportation costs for low transport distance rises slowly and reaches more than 50 €/cow for big herds. The average transport distance for big herds and low transport distance is 12.4 km (Figure 16). For high transport distance transportation and big herds transport costs rise up to 180 €/place at average transportation distance of nearly 40 km (Figure 16).

When transport costs are added to the fixed costs curve are plotted against herd size, Figure 17 shows the results.

Figure 17: *Fixed Costs and Transport Costs*

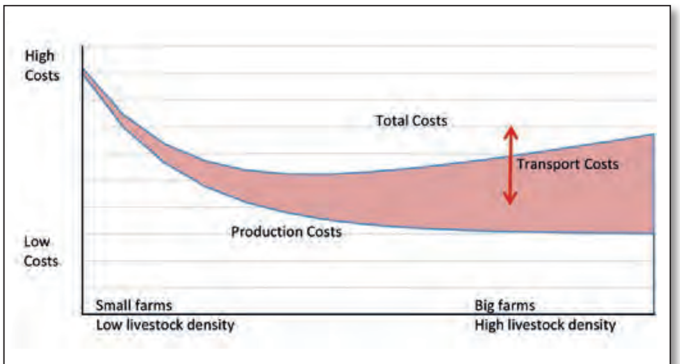


The fixed-cost-curve without considering transport costs decreases rapidly until 500 cows. Beyond this size, further cost reduction is at a much slower rate, and the curve approaches 700 € fixed costs per cow. Adding transport costs for low transport distance this curve has a minimum at about 1000 cows, although the cost increases either side of this are small. It makes little difference to fixed plus transport costs for herds over a wide range between 500 and 2000 cows, provided the transport distance can be kept low. If transport distance is high, then the herd size with least cost is a little less than 500 cows, and these costs rise appreciably either side of this optimum.

At herd sizes above 1000 cows and transportation distances more than 10 km there is no advantage of big herds over smaller herds. A similar calculation for pig production shows the same results.

These results can be generalized as shown in Figure 18. Small farms and low livestock densities lead to higher production costs and relatively low transport costs. For bigger farms and higher livestock densities production costs decrease slower and transport costs rise faster. Thus there exists an optimum for total costs regarding farm size and regional livestock density. This optimum differs between regions depending on farmland availability for absorbing nutrients.

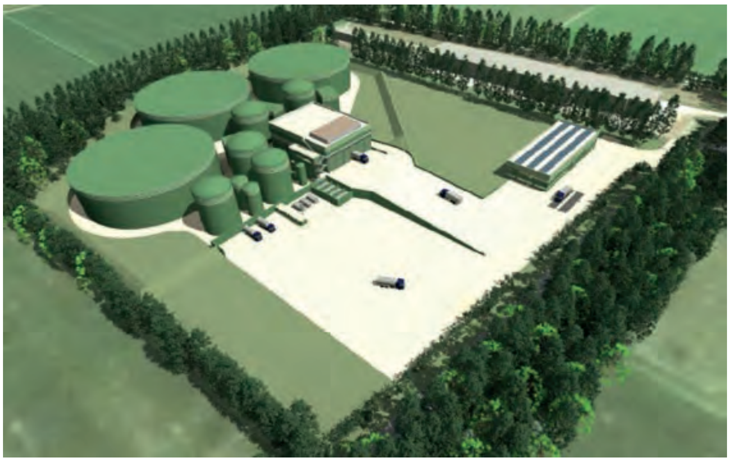
Figure 18: *Production Costs and transportation*



Nutrient Recovery Center Lombardy Region, Italy

A nutrient recovery project under construction in Italy (pictured in Figure 7) aims at recovering nutrients from sewage sludge, manure from laying hens, OFMSW (organic fraction municipal solid waste) and agro-industry by-products. This plant digests the input in a thermophilic process. In addition to the nutrients recovered for agricultural application methane is produced.

Figure 19: *Nutrient recycling center (Garuti, Nutrient Recycling, 2013)*



The project expects to process 120 000 t of sewage sludge, 10 000 t of OFMSWs, 5 000 t of manure from laying hens and 5 000 t of agro-industry by-products per annum. The amount of nutrients anticipated to be recovered annually are 1743 t of nitrogen, 1680 t P_2O_5 and 335 t K_2O. The power plant is expected to produce 8 200 MWh annually for power input (Garuti, Nutrient Recycling, 2013). Replication of plants such as this have the potential to recover significant quantities of nutrients across Europe with benefits to soil fertility, GHG emissions and water quality.

Conclusion and policy actions

Improving nutrient management and nutrient efficiency is a great opportunity to reduce pollution, economise the use of non-renewable mineral resources, produce renewable energy, and return more organic matter to the soil. Sources for organic fertilizer are livestock manure, plant and food industry residues and sewage sludge. Challenges for using these nutrients are sanitary properties, odor nuisance, fertilizer properties and transport costs. There are technical solutions to these challenges. Such processes are thermophilic digestion, separation and full processing like ultra-filtration. An alternative approach to reducing nutrient surplus is to rebalance the mix of livestock production and crop production within regions. The balance to be struck is to reduce the livestock density, and thus the manure output, to that which can be economically distributed and utilized by crops in the surrounding area. Finding this balance, in turn, requires knowledge of the relative economies of scale in animal production and the costs of transporting the manure. A methodology for investigating these calculations is illustrated for dairy production, and similar calculations have been carried out for pig production. Early results indicate that the optimal scale of production is likely to be smaller and more sensitive to herd size if manure has to be transported over longer distances.

There will naturally be some resistance to reducing the scale of animal production, but in such cases an alternative approach, to retain the benefits of economies of scale in livestock production, a possible solution could be to invest in regional nutrient management centers for treating organic residue, producing and providing higher quality recovered and recycled fertilizer for surrounding farmland.

Several policy options exist to support a more efficient nutrient use which has to be a component of the sustainable intensification of European agriculture. Information provision on the existence and extent of nutrient surpluses, and diffuse water pollution, is the first requirement to prompt the needed action. In order to support a better use of nutrients and increase nutrient efficiency, obligatory analysis of nutrient contents and crop and livestock nutrient plans may be required. Research and extension services help distribute knowledge about possibilities to improve nutrient use to farmers. New technologies for manure treatment and application of organic fertilizer give a great opportunity to improve efficiency of organic nutrients. Further political restrictions on nutrient use, and the enforcement of existing restrictions, lead to a higher pressure for farmers to pay greater attention to this subject. It should be taken into account that there are different regional requirements for nutrient use. Different soil properties and different public concerns require regionally varying thresholds. In addition to that there are different options for designing these thresholds. Limiting livestock density can be classified as a means orientated measure. More goal orientated measures would be limiting the nitrogen surplus or defining a minimum nitrogen use efficiency. A goal orientated political option would be to define a maximum level for nitrate in groundwater and penalize crossing of this frontier.

6.3 Biodiversity and agricultural production: supporting synergies[35]

Introduction

The loss of biodiversity and ecosystem services from Europe's agricultural land is still taking place.[36] One of the most important contributors of this loss is the intensification of agriculture, and changes in agricultural practices and land use. Some of the principal changes are listed in Table 16.

Table 16: *Agricultural causes of the loss of biodiversity and ecosystem services*

Intensification	Land use change
- use of fertilizer (input of nutrients) - use of pesticides - enlargement of field size - increase of frequency of machine use - standardisation of crop rotation - switch from spring to winter crops - cultivating monocultures, decreasing crop diversity - change in grass conservation, hay to silage - drainage and irrigation	- conversion of grassland into arable land - conversion of natural, semi-natural habitats and extensive used land into high-productive land - fragmenting of natural, semi-natural habitats - abandonment of land use

On the other hand a world-wide growing population, changes in food consumption styles, losses of food along the food chain, biomass production for energy and material use and other framework requirements induce a increasing demand for agricultural products and therefore additional intensification and land use changes (The Royal Society 2009, Tilman et al. 2001; Godfray 2010). Because biodiversity delivers a range of ecosystem services (TEEB 2010; Beck et al. 2006; Plieninger et al. 2012), which partly influences agricultural productivity (Östmann et al. 2003;Perfecto et al. 2004; Bengtsson et al. 2003 in Tscharntke et al. 2005), it is also in the interest of the agricultural

[35] This case study was prepared by Christine Krämer, Wolfgang Haber, Alois Heissenhuber, Agricultural Production and Resource Economics, Technische Universität München-Weihenstephan, Alte Akademie 14, D-85350, Freising-Weihenstephan.

[36] There is a large literature supporting this assertion, see for example, Butchart, S.H.M. et al. 2010, Buckwell, A. & Armstrong-Brown, S. 2004, Bundesamt für Naturschutz 2007, Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz 2007.

sector to preserve biodiversity. There are indications that a tipping point of ecosystem services may exist, so that ecosystem services are not longer delivered if the tipping point is passed (Power2010:2968). So the questions to be answered in the context of sustainable intensification are:

- How can biodiversity and ecosystem services of biodiversity be increased without decreasing (or even also increasing) agricultural production?

- Which approaches, measures and instruments are useful to reach this goal?

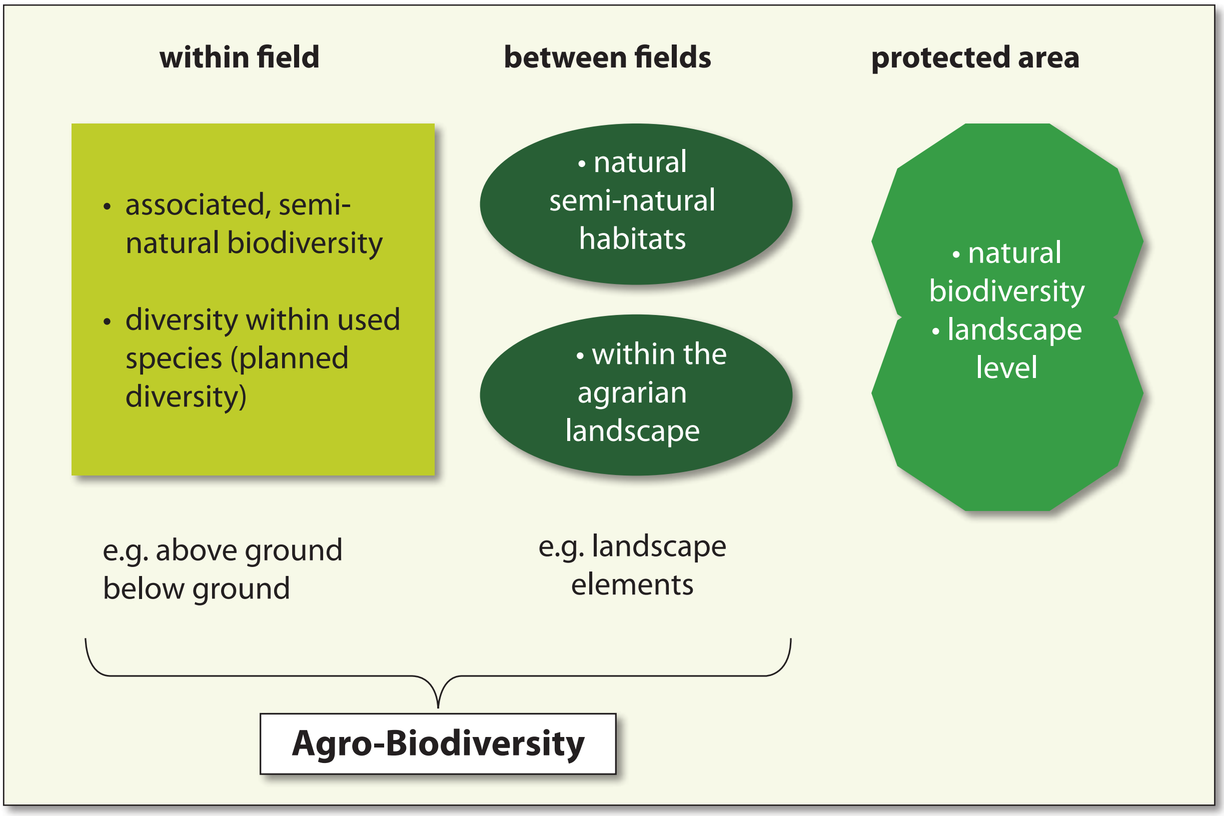
- Which impacts have these approaches, measures and instruments on economic and social (and other ecological) factors?

This case study focuses on agro-biodiversity. What this embraces is summarised in Figure 1. It refers to those aspects of biodiversity, which are connected to agricultural production and include both the extensive soil biodiversity which is below ground as well as the more visible biodiversity above ground. It includes the genetic diversity of crop plants and farmed animals, as well as the variety of natural and semi-natural habitats and species within the agrarian landscape (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz 2007:9). Protected areas are not considered in this chapter.

Figure 20: *Biodiversity: What are we talking about?*

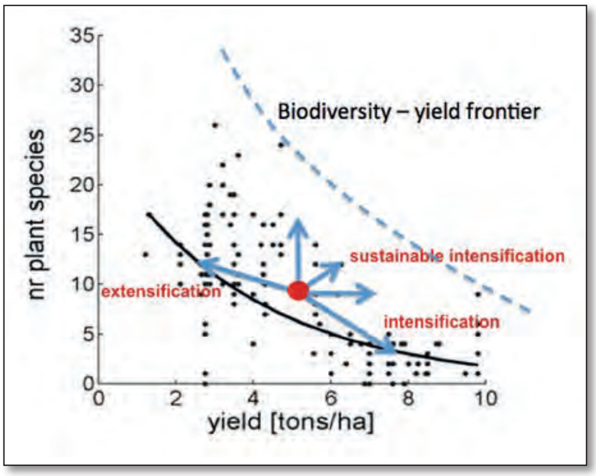
This case study discusses how biodiversity has to be protected by the way agricultural production is managed, whilst at the same time trying not to reduce agricultural output. A simplified representation of the relationship between biodiversity, measured as the number of species in a given area, and agricultural output from the area, measured as crop yield, is shown in figure 21. This figure is adapted from Geiger et al. 2012 to which the arrows and the dashed biodiversity-yield frontier has been added. Two generally observed features of this relationship are first, it is a negative relationship indicating that biodiversity declines with increasing yield, which comes about with the intensification of production. Second there is a great deal of variability from one site to another. For any given yield there can be a wide range in the number of species present; and for a given level of biodiversity, a wide range of agricultural productivity can be observed. Most sites are not close to the frontier of this relationship. It is this aspect which may offer the opportunity to exploit sustainable intensification.

Figure 21 also illustrates another way of representing the vocabulary of extensification, intensification and sustainable intensification. Consider the red point in the diagram, from this combination of yield and biodiversity an increase in biodiversity can be reached by reducing yield (the north-west pointing arrow), this is often called extensification. Many agri-environmental programs follow this mechanism. The word intensification often means, that as yield is increased this brings about a reduction in biodiver-



sity (the south east pointing arrow). Sustainable intensification indicates a simultaneous increase of both yield and biodiversity, or an increase in one with no detriment to the other (the other three arrows).

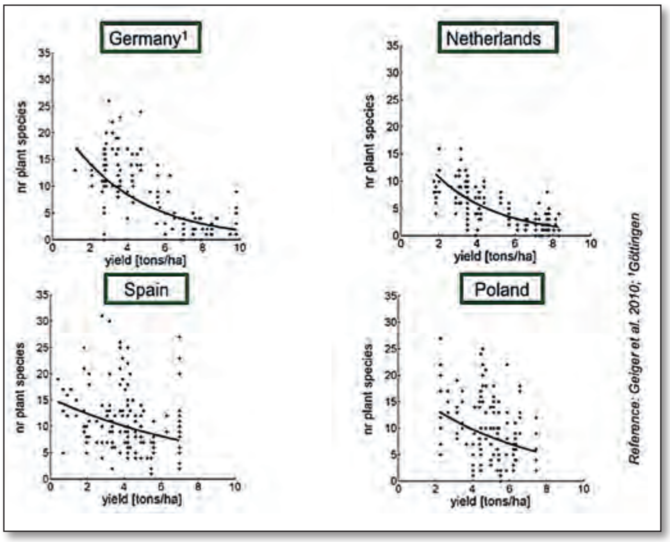
Figure 21: *Sustainable Intensification - Biodiversity*



Each of these sustainable intensification arrows point towards the notional food - biodiversity frontier (the dashed line) which shows the maximum achievable combinations of biodiversity and productivity. It is the very existence of this observed variability in current production combinations which offers the possibility that there could be considerable scope to achieve sustainable intensification if the management of most sites were to move them closer to the frontier. This gives a neat diagrammatic illustration of what it means to be more resource efficient and to move to a path of sustainable intensification.

Figure 22 confirms that the variability illustrated in Figure 21 is indeed widely observed. This figure shows data for four EU Member States (Geiger *et al*., 2010) and also other studies by several authors, (Buck et al. 2006, Donald et al. 2001; Kleijn et al. 2009; Firbank 2007) showed this relationship. This confirms the observation that there can be a very wide range

Figure 22: *Biodiversity in relationship to intensity in four EU Member States*

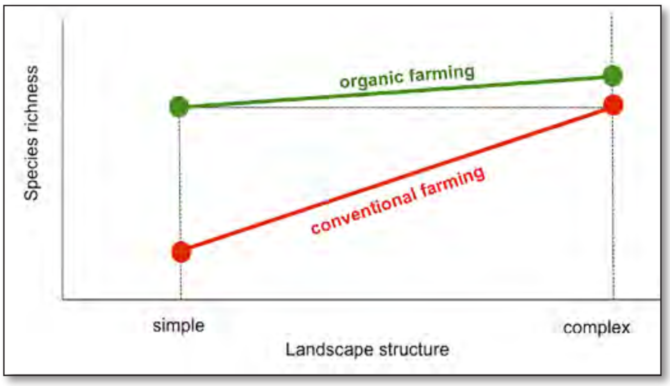


of biodiversity values for a given yield level, and vice versa. There has been analysis of the explanatory factors which lie behind the observed variability and it is suggested that the influence of landscape structures is important. These structures are natural and semi-natural habitats in and adjacent to crop fields. On many farms, and with suitable incentives, the quantity and quality of these structures many be managed to help farms closer to the frontier.

Biodiversity and landscape structures

Tscharntke et al (2005) suggest that the maintenance of natural and semi-natural habitats seems to be able to balance intense agricultural production up to a critical point.

Figure 23: *Species richness in relation to local management (extensive vs. intensive) and landscape structure (simple vs. complex)*



Source: Tscharntke et al. 2005

Because of the many disturbances on managed agricultural land and the different demands of species during their life cycle, the existence of natural and semi-natural habitats is essential. Also, in some circumstances the agricultural land itself is needed as habitat. Many species depend on extensively used agrarian land which has been under human management for centuries. When intensification occurs it not only influences the managed agricultural area but also the neighbouring habitats. Fig. 4 shows two fields one without landscape elements and, below, one with linear landscape elements – there is more biodiversity in the lower example and even if the yield of the farmed land is the same, in the second case slightly less land is used by agriculture.

Figure 24: *The influence of landscape structures*

Source: Computeranimation und Visualisierung:
Prof. Schaller Umweltconsult GmbH, München 2013

Analyses show that the inclusion of natural and semi-natural habitats, i.e. through landscape structures, as well as some extensification of agricultural production (local influence) is important to secure biodiversity in agrarian landscapes.

Success of conservation measures in different structured landscapes

Different structured landscapes therefore have different requirements for the formulation of conservation measures (see Fig. 6). In landscapes with few natural and semi-natural habitats (2-20%) the inclusion of such habitats has the most positive effect on biodiversity (Tscharntke, T. et al. 2005). But also the extensification of the production on the farmed land has positive effects, as long as measures are implemented on large-areas (Kleijn, D. et la. 2009; Tscharntke, T. et al. 2005). In landscapes with many natural and semi-natural habitats biodiversity is generally higher. In these landscapes either strong intensification of agricultural production (Kleijn et al. 2009; Batary, P. et al. 2010a) or the opposite, an abandonment of agricultural production, can have negative effects on the biodiversity. Both kinds of destructive development therefore should be minimised. But in complex landscapes some degree of intensification of agricultural production may be possible, without decreasing biodiversity. Measures to create spatio-temporal variety like crop rotation on the field and in the landscape, cutting time requirements and measures to increase efficiency can be successfully implemented in all types of landscapes and are able to cause increases in biodiversity and agricultural productivity simultaneously. Broad conservation and management concepts like Differentiated Land Use (DNL) (Haber, W. 1971. in Haber, W. 2012/2013), Eco-agriculture (McNeely, J.A. & Scherr, S.J. (2001) and Agroforestry can also be implemented in many regions, but their practicability has not been tested yet. These ideas are summarised in Figure 25, which shows that the options for finding a path of sustainable intensification differ depending on the starting position, i.e. the existing intensity and complexity of landscape structures. The emphasis throughout this case study is to increase conservation outputs with least disturbance to agricultural output. Where land is already highly intensively farmed some reduction in agricultural output may be unavoidable if biodiversity and non-food ecosystems services are to be increased. But in some cases, for example avoiding the abandonment of agriculture the conservation and agricultural outputs may go hand in hand.

Figure 25: *Conservation measures corresponding to landscape structure*

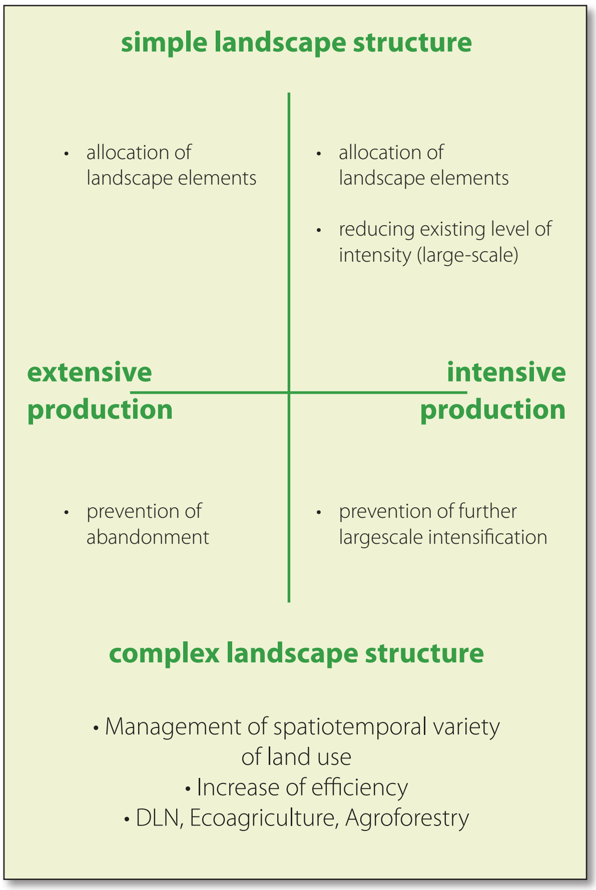


Figure 26 presents a more detailed list of conservation measures but this time breaks them down according to their level of implementation, within-field or between-field, and by their level of impact, at the landscape or field level.

Figure 26: *Conservation measures and corresponding level of implementation and impact*

Landscape		Field	
between-field	within-field	within-field	
between-field	**Management of spatiotemporal variety of land use**	**Extensification**	**Increase of efficiency**
allocation of ecol. set-aside (biodiversityfriendly use corresponding the spatial and temporal factors possible e.g. agro-forestry, late cutting, ...)	variety in crop rotation (spatial, temporal) Late, differentiated cutting time reduction of field size Prevention of abandonment of land use	reduced use of fertilizer reduced use of pesticides Minimum tillage Ecol. farming	precision farming (e.g. no prophylaxis use of animal medicine
Eco-Agriculture DLN Agro-forestry			

Policy instruments for encouraging these conservation measures

There is already a wide range of environmental measures incorporated into the Common Agricultural Policy, which can be directed towards the conservation measures discussed here to help biodiversity in arable areas. These were reviewed in section 5.1.2 above. Here are discussed three other kinds of instruments which are not widely in use yet. First are cooperation measures. Many species require a biotope system or multifaceted management of agricultural land over an area much greater than individual farms. In such situations the cooperation of farmers is necessary to fulfil the requirements of species. This can only be achieved at sufficient scale if many farmers work together through cooperative measures. Related to this broader landscape approach to conservation measures, it may be necessary to bring regional budgets and regional institutions together with a range of stakeholders to define goals and the measures to reach those goals at a level below the country, province or Land. This is required because location factors as well as social demands differ greatly between regions. So responsibility and possibilities to act should be given to each region. The LEADER approach can be a model to help further develop this instrument. A third additional approach which may be necessary is the use of planning instruments. Because species have different requirements during their life cycle and all requirements have to be fulfilled for the conservation success, instruments of planning could usefully be deployed.

Further Steps

The term sustainable intensification implies a simultaneous focus on environmental aspects of farming and agricultural production at the same time and in the same field. This is a broad definition and the way it will be applied will depend on the specific circumstances or each region, farming system and time. A more spatio-temporal understanding of how biodiversity protection fits the concept of sustainable intensification is useful. The combinations of approaches and measures to increase biodiversity without decreasing, or even increasing, agricultural production in tune with the surrounding landscape have to be evaluated on a case by case basis. Such site-specific approaches can also include a local intensification of agricultural production without decreasing biodiversity, although this will generally only be possible in the presence of complex landscape structures.

Therefore further research is needed to

- Improve the knowledge about positive trade-offs between biodiversity and agricultural yield
- Focus on the landscape aspect of biodiversity conservation: which measures and combination of measures can be implemented in different landscapes to increase either biodiversity or agricultural production without influencing the other factor in a negative way
- Definition of "new" measures and instruments like

cooperation measures, regional budget, provision of biodiversity or planning instruments

- Examination of the practicability of eco-agriculture, e.g. DLN (differentiated land use), and agro-forestry.
- Evaluate the effects of implementing the defined measures on economic, social and the other environmental factors such as water quality and GHG emissions.
- Evaluation of the influence of further framework requirements (e.g. consumption styles) concerning their impact on biodiversity conservation
-

6.4 Some lessons arising from the case studies

The soils case study is a practical illustration of ideas discussed in sections 5.1.1 and 5.1.3 on assembling and using evidence to indicate aspects of environmental sustainability. The methodology presented was completely dependent on officially collected data on soils from the LUCAS topsoil and the CORINE land cover surveys, indicating the importance of having the scientific data available at suitable scale.

It is the way the data is used which depends on the exercise of scientific judgement and experience. This is needed first to decide which properties of soils are relevant to encapsulate the resilience and performance of soils which enables them to tolerate, and indeed perform, under varying intensities of agricultural production. In this study six aspects were selected. The second major judgement was exercised to derive thresholds defining classes of land, suitable to cope with intensive agriculture at one end of the scale, and unsuitable at the other end.

Implicitly this approach has offered judgment of where to draw the line or threshold between sustainable agricultural soil management and unsustainable management. It is instructive that two lines are drawn, between class 1 and 2, and between 3 and 4 of the four sustainable intensification classes defined on p66. This double threshold interestingly illustrates the fuzzy nature of sustainability thresholds (discussed in section 4.2.2). Classes 2 and 3 can be described as being beyond the threshold for sustainable intensification. IN the case of class 2 it is because at least one of the six soil quality criteria is outside the acceptable range. But there is an implication that if it were possible to attend to the out-of-range criteria, for example by improving the pH or soil organic matter, then it might be possible to reclassify this soil into a higher class more suitable for intensive agriculture. Equally the class 3 is only suitable for sustainable intensification subject to restrictions, i.e. provided that attention is paid to whichever criteria are on the borderline of acceptability.

It is only class 1 where it is judged that the soil conditions are so fragile that no intensification is acceptable, and these are likely to be soils where existing agricultural production should be extensified. This is effectively a judgement call that the threshold of sustainability (with respect to soils) is the combination of soil quality criteria defining this class.

The authors of this case study are careful to state that declaring that a soil described as suitable for sustainable intensification (a) is not a blank cheque for any kind of further intensification, the qualifier sustainable is critical, and (b) this passes no judgement on whether the current level of intensity, or any proposed intensification, satisfies the appropriate protection of water quality and quantity, GHG emissions, other atmospheric pollution, biodiversity or landscape. These require separate analysis.

The publication of maps showing land suitable, and land not suitable, for intensification and tables showing the proportion of arable land in these categories, will doubtless stimulate much discussion of the thresholds, and perhaps even horror from those who are apparently engaged in intensive production on land classified as unsuitable. This is probably the most useful aspect of such analysis: to provoke such discussion and then a refinement of the criteria and thresholds.

It is instructive that a great deal of painstaking work is required to appraise just one aspect, albeit a vitally important one, of sustainability. To make a full judgement of the sustainability of agricultural systems in principle would require comparable studies on each of the other dimensions of sustainability.

The other two **case studies on nutrients and biodiversity** are essentially about resource efficiency.

The nutrient study deliberately starts at the strategic level to illustrate the non-linear nature of an important part of modern agriculture. Crop producing areas import considerable nutrients, nitrate produced at large cost in fossil fuels and mined non-renewable phosphate. The crops are consumed either as human food in urban areas where a significant fraction of the nitrogen, phosphate and organic matter ends up in sewage treatment works, or as animal feed in intensive livestock production regions. There is considerable leakage from this system causing water and atmospheric pollution. Only a fraction of the N and P introduced at one end of the process is effectively utilised in human metabolism. This is extremely resource inefficient. It is a system crying out for recreating more of a cyclical process to recover the nutrients and organic matter and return it to the soil in the arable areas.

The challenge is to find tractable ways to analyse the options for recovering and recycling the nutrients. This is what the nutrients case study set out to do. One of the problems of closing the nutrients cycle is that the materials to be dealt with are very high volume and low value as they are generally highly diluted. They are also unpleasant materials with some degree of biological hazard. Yet the core problem is the need to transport the nutrients from where they are produced (towns and intensive livestock zones) to where they are needed (the main arable cropping areas). Another handicap is that the materials involved are all too often labelled as wastes rather than as resources. Although these features present considerable technical challenges, a great deal of knowledge and experience exists on the technologies to separate, filter, and concentrate such materials and to extract the required nutrients. The case study therefore focuses on the less understood and researched aspects which are the relative economic costs of different treatment and transportation paths.

Interesting policy challenges emerge from the analysis which shows that there is a trade-off between economies of scale in livestock production and the costs of transporting manures or recovered nutrients and digestate to the arable areas. As tighter regulation particularly on water pollution restricts the disposal of manure in areas easily reached from livestock operations, this means either shifting materials longer distances or reducing the scale and concentration of livestock production, that is, relocating this production. Given the considerable investment involved this is not an easy matter to resolve, but only with the kind of analysis present can these choices begin to be explored.

Why is this reported in a study on sustainable intensification? Because it deals directly with a challenge to maintain competitive livestock production (all the while there is EU and global demand for these products) whilst seeking to significantly improve the environmental performance of this production. The recycling of nutrients offers the possibility to do this by a radical change in manure management which can reducing nitrate and phosphate pollution to water. Combined with the recovery and recycling of nutrient from sewage waste this could also significantly increase the return of organic material to soils – and a further bonus could be any energy (methane) produced from the digestion of these materials. The challenge is to get the economics of the processing and transportation to work, and to get the public buy-in for the recycling of nutrients recovered from sewage sludge.

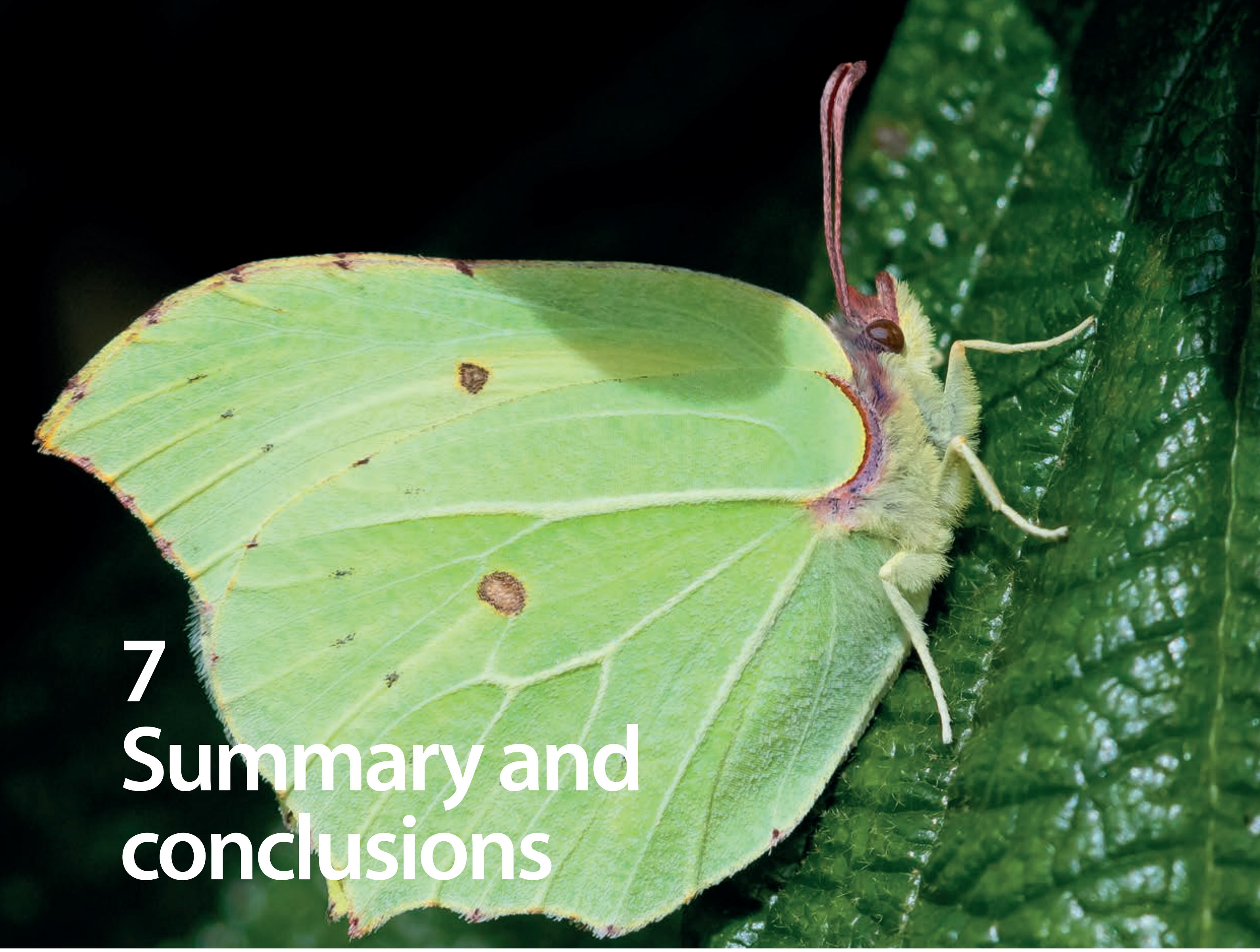
The third case study on biodiversity offered a quite different perspective on the ways that sustainable intensification can be manifest. This case study particularly explored the kinds of policy instruments which can be used to combine intensive arable production with much higher performance in biodiversity protection.

A particularly revealing aspect of the study was the empirical data on the variability of yield and biodiversity combinations discovered in arable fields in EU Member States. It was discussed in section 5.2 that it is generally observed from farm management data that there are always considerable differences between the economic performance, for example in production costs per unit of output or in productivity measures, as between the highest and lowest quartiles any sample. It was suggested that there is every reason to believe that the same or greater variability will exist in environmental performance of individual farms (or fields). This is exactly what is observed in data presented in the case study on biodiversity. The importance of this observation is that it implies that a high proportion of agricultural production in Europe may be taking place well inside the production possibilities frontier. This in turn implies that there is equally great scope to achieve gains from sustainable intensification which moves farms (and field) management closer to the frontier.

This is what is meant by greater resource efficiency – producing more with the same or les resource. But importantly it could happen by increasing the biodiversity with no detriment to yields or the opposite. Sustainable intensification makes no presupposition whether the output which is intensified is the conservation good or the agricultural product.

This case study opens the door to seek out comparable data on other measures of environmental performance to plot against farm productivity (yields) and then to perform statistical analyses to test if the variability in environmental performance is relatively uniform over the yield range or shows a distinct pattern. Such data could also provoke studies to explain more of the variability in biodiversity for a given yield performance. The case study suggests that the presence or absence of structural landscape elements is an important factor. The contribution of the study is to indicate the importance of collecting this kind of information.

Finally, understanding the source of variability in environmental and economic performance is also critical to making decisions about the appropriate policy measures to steer farms to a path of sustainable intensification.



7 Summary and conclusions

Context and purpose

The concept of sustainable intensification has come to the fore in recent years as a response to the challenges confronting ***global*** food security. These challenges are principally continuing population and economic growth in the face of scarcities of agricultural land and water and the dangers posed by climate change, agricultural pollution and biodiversity loss.

This project was initiated by the RISE Foundation to explore the relevance and meaning of the concept for the European Union and for its future agricultural policy. An important feature of the project was that a wide group of experts, officials and practitioners were consulted through a series of three events held in Brussels. The first of these was in the European Parliament on 28 January 2014, the second at a workshop on 31 March and the third in a series of breakout sessions at the Forum for Agriculture on 1 April.

The clear consensus which emerged from these consultations was that Sustainable Intensification *is* a useful, globally based, concept which aims to steer farmers to land management which has a better balance between food production and the environment.

The prime logic behind the phrase is the assertion that it would be unacceptably damaging to climate and biodiversity if the necessary future expansion of global agricultural production to feed the growing and higher-income population were based on further conversion of forest, grasslands and wetlands. There has been large-scale destruction of these ecosystems over the last 150 years and much evidence to show the biodiversity loss, pollution, and climate impacts of this land use change.

This leads to the conclusion that the next increment in global food output must come very largely from higher yields on existing agricultural land, which amounts to "intensification" in the sense adopted here. This was the main route through which agricultural production expanded in the 20th Century. The difference in future must be a step reduction in the negative environmental impacts of agriculture. These are the arguments which lead ineluctably towards the concept of sustainable intensification of existing agricultural land. No assumptions are made in the report about targets for production growth globally or in Europe, however it is an underlying assumption that some production increase is required.

It is constantly, and rightly, asserted that tackling the issue of global food security must deal with policies and efforts to contain growth in food consumption, e.g. through reduced waste, as well as expanding supplies. There is no disagreement at all with this assertion yet this report confines itself to issues of agricultural production. The reasons are, first, the expertise and interest of the organisations and researchers involved. Second, the demand side issues (food waste, food consumption and dietary patterns), and the policies to steer society towards more sustainable consumption involve subjects, instruments, approaches and institutions utterly different than the measures directed towards agricultural production and environmental land management by farmers which are the subject of this report.

The main purpose of this project was to discuss the concept of sustainable intensification in the context of the European Union. It was a desk based study but it included some intensive consultation with expert opinion through two workshops. The project was also built around three case studies which were part of other larger on-going research projects and which provided illuminating examples of how sustainable intensification can usefully be explored in empirical research. One case study deals with soil resilience and performance, the second concerns the better recovery and recycling of plant nutrients to reduce water pollution. The third case study explored how better balance between biodiversity and crop yield in arable crops can be achieved.

Definition

There is no generally accepted definition of sustainable Intensification, the definition used throughout this report is: *Sustainable Intensification means simultaneously improving the productivity and environmental management of agricultural land.*

The phrase is used throughout this report in the sense of being an aspiration. After a brief conceptual explanation of what this term means and what it seeks to achieve, two general conclusions about sustainable intensification are:

- *Overall, sustainable intensification does not point to a single development path for all agricultural systems or farms. The direction of the path and the actions required to meet it will depend partly on the conditions, particularly the current agricultural productivity and environmental performance of that farm or system.*
- *A sustainable intensification path could mean an increase in the output per hectare of environmental services of the farm and/or an increase in agricultural products per hectare, it does not* <u>*only*</u> *mean the latter.*

The application of the concept to the European Union

Five considerations led to the conclusion that the globally motivated concept of sustainable intensification when applied to the EU must place most emphasis on the first word of the couplet. The explanation is developed at some length in Chapter 3. It starts by observing that most of the new pressure for additional food production will arise outside the EU. Added to which EU food production is already amongst the most intensive in the world, and the resulting steady productivity growth in Europe has meant that the area of EU agricultural land has slowly been falling. Agricultural encroachment onto new lands is not the problem in the EU; indeed the reverse process of agricultural abandonment is more often of concern for environmental and social reasons. The critical EU issue is that the past intensification of agriculture is associated with pervasive undesirable environmental impacts in Europe. An additional concern is that agricultural imports into the EU are associated with environmental damage in the exporting countries. Therefore it is argued that the role of European sustainable intensification be to show how high intensity, productive agriculture, can be combined with much higher standards of environmental performance. The emphasis has to be to find ways to continue the process of technical change in food production to radically improve the resource efficiency of European agriculture and in the process to meet European citizens' ambitions for high standards of biodiversity, climate, soil, water and cultural landscape protection. In short, in the EU interpretation of sustainable intensification must place most emphasis on improving sustainability.

Deconstructing sustainable intensification

In the context of agricultural production, **intensity** is well defined as a ratio of inputs or output per hectare. It is relatively easily measured but it is generally denigrated! In contrast, **sustainability** is not well-defined or measured but is universally supported!

Intensity and intensification. When reference is made to "intensive agriculture" this invariably refers to a ratio of a restricted range of inputs per hectare of land. Intensive agriculture is most frequently thought of as utilizing a narrow group of specific kinds of tangible physical inputs: fertilizers, pesticide, water and machinery for crop production and high density housing systems for animals. There are understandable reasons for focusing on these specific inputs particularly because if they are used inappropriately they can become pollutants of water and atmosphere and destroy habitats and biodiversity. An accompanying aspect of agricultural intensification has been the specialization, and simplification of production often associated with structural changes in farming. This intensification of management generally contributes to more output per hectare.

The discussion sought to de-stigmatise the word intensification in the sense deployed here. The prime objective of sustainable intensification is not intensification *per se*, and certainly not an increase in intensity of use of environmentally harmful agricultural inputs. Rather the prime objective is to improve the resource efficiency of agriculture.

A great deal of intensification can and must, in future, take the form of added knowledge which will affect how physical inputs are combined and managed. A suggested shorthand to describe what sustainable intensification means is ***more knowledge per hectare***! Similarly, increasing levels of knowledge are needed to manage the ecosystem services on which agriculture relies. Intensification of agriculture, especially in Europe is therefore not primarily about the use of more fertilisers, pesticides and machinery applied per hectare, but the development of much more knowledge intensive management of scarce resources to produce food outputs with minimal disturbance to the natural environment.

A valuable route to destigmatising the process of intensification would be to place the environmental outputs of land management on an equal footing with the food and energy outputs. Unfortunately the word 'production' has been deeply embedded to refer only to planned outputs which are marketed and sold. It is very hard to imagine that this usage can change. This is a great pity. A virtue of the relatively new language of ecosystems is that it seeks to place the provisioning services of nature, e.g. food and energy which are produced and sold through market-based processes, on the same basis as the supporting, regulating and cultural services, which are non-marketed. Indeed the latter are referred to as the outcome of market failures as they display aspects of public goods. There are many areas of Europe where these ecosystem services have greater social value than the agricultural outputs produced, or producible, from the land. The problem is that because the market processes fail, these services are not valued, or less valued, by producers and so they are consistently undersupplied. A correct interpretation of sustainable intensification should embrace examples where the production to be intensified per hectare can equally refer to the conservation outputs, e.g. pollinators or fledged lapwings per hectare, as to agricultural products.

In short, high intensity does not automatically mean unsustainable agriculture or unacceptable environmental performance. Where it does, there may have to be reduction in intensity of the offending inputs or practices. The case studies in Chapter 6 on soil resilience and nutrient surplus in some livestock areas provide examples of this.

Sustainability and sustainable development.

The 1987 Brundtland Report defined sustainability as "*meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*". This concept has since been built into International conventions on Biodiversity (1992) climate change (1992) and combating desertification (1994). In the EU the concept was formally introduced in the Gothenburg Strategy for sustainable development (2001) and subsequently in the EU Strategy for sustainable development (2006) before being enshrined in Article 11 of the Treaty of the Union (2008).

Whilst there is universal agreement on the desirability of the concept, there are quite strongly held differences on how it is interpreted and what it means for policy and practical action. Some of these differences are philosophical or ideological and do not readily lend themselves to resolution by appeal to empirical evidence. These are important, because if there is disagreement about sustainability, then this will follow through into sustainable intensification.

There is general agreement that sustainability must be considered under the three pillars: economic, environmental and social. However, there are disagreements about which pillar, if any, is paramount. In practice the definition and measurement of economic sustainability is relatively straightforward, these considerations are highly visible in public debates, and the interest group most concerned is clearly defined, active and effective in defense of its interests. In EU agriculture this is well illustrated in the process of CAP reform. The definition of environmental sustainability is multi-dimensional and more complex, its measurement is much more difficult. Rightly, this is the area of most work and debate. Conceptually, the social dimension is the least developed, measured and acted upon. The result is that despite the lip service paid to the three equally important pillars of sustainability, it is common to observe that the analysis which follows the word is focused mostly on the environmental dimension.

Weak versus strong sustainability refers to the possibility that natural capital – especially biodiversity and the ecosystems which it produces – can be substituted by human, physical or financial capital in improving human well-being. Proponents of weak sustainability accept some degree of substitution can be made, and has been; proponents of strong sustainability say it should not, no decrease in natural capital should be tolerated. A recent summary of this debate suggested that weak sustainability is associated with growth optimists who see natural capital as a production factor and a source for human welfare. Whereas strong sustainability supporters stress limits to economic growth and see natural capital as a basis for human survival (Kaphengst 2014).

There is a related debate on whether sustainability implies the existence of limits, thresholds or tipping points beyond which a system cannot recover, going into irreversible decline. There are strong beliefs that some such limits exist, and that the effects of human activity have taken us, or are about to take us, beyond these thresholds. However outside of climate change there has been little progress in identifying and robustly quantifying these limits as they may apply to European agriculture. As a practical resolution, many of the limits suggested in the literature to define safe operating boundaries are legislative standards. This is unsatisfactory. It would seem important to put more effort into detecting limits and the proximity of current activity to them. Such information should help identify steps that could be taken to avoid running into the limit. However, another challenge to the process of identifying and measuring environmental thresholds is deciding at what scale or level to measure them: locally, nationally or globally?

A special mention should be made of the particular uncertainties created by climate change. The time scales are not clear, but a distinct risk to sustainable intensification, is that sufficient temperature or sea level rise can simply eliminate agricultural production from certain areas where adaptation measures are inadequate or inapplicable. Of course in these circumstances the ecosystems underlying agriculture will also be lost. Investigation of these thresholds deserves more active research.

Given these difficult, conceptual and unresolved aspects of sustainability it is perhaps not surprising to find that the empirical literature which sets to measure the sustainability of specific agricultural systems is not very conclusive. Our review of 49 academic and other investigations into the sustainability of farming systems turned up 500 different indicators of sustainability. Of these 202 could be characterised as social, 95 as economic, 198 as environmental, and the final five as 'other'. There was little convergence on a core set which should always be included. It was also disappointing to find that the considerable efforts devoted by the European Institutions to define indicator sets, for example the IRENA indicators for the agri-environment, have not found their way to be used as a basis or starting point in the empirical analyses of agricultural sustainability in academic literature or by governments. There were a great many, some highly sophisticated, attempts to combine or aggregate the sustainability indicators into an overall index, but again no convergence has emerged on how this is best done, or indeed if it is a useful endeavour.

Conclusions drawn from this review of the concepts behind sustainable intensification are:

- Input intensification *per se* is ***not*** the goal, but may well be a consequence of achieving these goals.
- The input which has to be intensified everywhere is knowledge per hectare.
- The prime goals of sustainable intensification are a resource efficient agriculture with significantly higher environmental performance. Ecosystem degradation is itself reducing agricultural productivity.
- Sustainable intensification means improving productivity of crops and animals whilst reducing: the leakages of nutrients, crop protection chemicals and greenhouse gases; soil erosion and biodiversity, habitat and species loss; and expanding conservation outputs of agriculture.
- Because intensity and sustainability of agricultural systems vary enormously and from site to site, sustainable intensification development paths will differ widely between locations, farming systems and individual farms.
- Sustainable intensification will mean increasing agricultural outputs in some cases and conservation outputs in others, and in some situations, both.
- It would be helpful if academic and commercial attempts to measure sustainability in agricultural systems were to build on the basis of the official indicator sets.
- More effort should be expended to examine the evidence on environmental thresholds relevant to EU agriculture, particularly those related to climate change.
- In the absence of sufficiently comprehensive or specific evidence on thresholds, then it would be more scientifically defensible to talk about environmental, economic and social *performance* rather than *sustainability*. This would better fit to the use of legislative standards as proxies for thresholds as performance below such standards is clearly unacceptable.
- Sustainable intensification can be seen as the latest manifestation of a long line of attempts to demonstrate to farmers that they have a twin role of producing food and environmental services.

Actions to progress sustainable intensification

It has been emphasised that a sustainable intensification path, can only be defined with respect to particular farm systems in specific locations and with respect specific concerns. There is no single and simple formula to indicate the path of sustainable intensification for any farm or group of farms. Achieving it will be a process over time and the actions required could involve participants and stakeholders in agriculture, up and down-stream of agriculture and other interests in rural communities and in rural land management. The actions are discussed under two headings, first those collective actions which will have to be taken by public authorities and second the actions which will primarily be the responsibility of private sector land managers and the other businesses in the food chain.

A key common action required of both public and private sectors is research and development. There is clear evidence that agricultural productivity growth responds to research and development efforts. Since the food price spikes of the period 2007-2011 the importance of strengthening the public sector research for agricultural development has been well recognized. It is also now well acknowledged that the target of agricultural R&D has to embrace the twin goals of agricultural productivity and the environmental performance which accompanies agricultural production. This is particularly so for public sector research but it is visible in the private sector too.

It is suggested that, broadly, the amount and makeup of agricultural R&D, and the objectives which have been set for it are not the prime obstacles in making progress to set EU agriculture onto a path of sustainable intensification. The more significant challenges are getting the most effective information and policy framework in place and motivating and enabling land managers to adjust what they are doing.

Actions for the public sector

The two broad areas where collective societal actions are required are to assemble and publicise the evidence on the economic, environmental and social performance of agriculture, and to put in place, and appropriately resource, the mix of policy measures required.

As far as ***assembling indicators*** is concerned, the Member States and European Union have invested considerable resources over many years to define indicators of economic and environmental performance and to devise methods for collecting and collating the data on a common basis for the EU. There is less work conceptualising and collecting data on the social dimension of sustainability. These efforts are summarised in the report.

The area of least difficulty is in measuring economic performance. The EU system of aggregate economic accounts for agriculture and the farm accountancy data network is constantly evolving to satisfy the need for this information. There is good measurement of the economics of agricultural production in Europe. However there are two areas of deficiency in farm-level data collection. They are the non-agricultural incomes of farming households, and environmental performance at farm level. Whilst wider rural development and agri-environmental policy have become a steadily larger part of the policy there has not been a parallel development of the farm-level database to support these policies. This has already been a handicap in providing the evidence base for policy change – not least, for example, in supporting the case for the greening actions under Pillar 1 of the CAP. This deficit can be an obstacle to the rollout of sustainable intensification.

Even when the raw information, of wider environmental indicators and from farm surveys, is available there is still considerable work to be undertaken to understand the relationships between land management practices, the factors which drive them, and the impacts on environmental variables. Monitoring developments is a key part of this process which is all too frequently given low priority by governments. Such information is vitally important for policy determination and design. This work is undertaken through specific research contracts at both EU and Member State level and of course in the academic community. It is vital that the pace of such work is maintained because there is a long lag between commissioning such research and its results being available for new policy design.

Policy actions are required for both aspects of sustainable intensification: that is improving the productivity and the environmental management of agricultural land. These policies are reviewed in the report under the four headings: R&D, education, advice and innovation; environmental policy; agricultural policy; and brief mention of other collective actions to stimulate provision of environmental services.

R&D, education, advice and innovation. At risk of being accused of complacency, it is suggested that in the main strands of research - private and public, EU and Member State - the broad lesson that sustainability objectives have to be built-in to programmes to stimulate agricultural productivity has been taken on board. That it has to be done is therefore not in dispute. Whether it is being done adequately is another matter. The greater challenge is to translate the fruits of the research on combining high performance for the environment and productivity into changed practice on the ground. This is partly a matter of education, training, information and advisory services. But it is also strongly linked to farmer motivations and attitudes and the market and policy incentives which confront them. Agricultural education and funding advisory services are mostly matters for Member States. There are widely different degrees of provision on these activities around the EU.

At the EU level the need for advisory services and for innovative approaches is well recognised and is an important dimension of the new Rural Development Programmes to operate from 2014-2020. In particular the European Innovation Partnership (EIP) for agriculture is entitled 'Agricultural Productivity and Sustainability' (Commission, 2012). It seeks to be doubly innovative, in the bottom-up approach to the identification and auctioning of projects, and in recognising that the innovative projects will take a wide variety of forms. These could be technological or non-technological, involving new or traditional practices and operating at a range of scales. This reflects what has been observed about sustainable intensification – its expression can be as diverse as European agriculture is itself. It will not be embraced by a few big ideas, but by the practical application of a multitude of developments.

Environmental Policy. It is suggested that there are few specific new or radically different policy sets required to steer EU agriculture to a path of sustainable intensification. Directives most relevant to sustainable intensification of agriculture have been agreed for Birds and Habitats, Nitrates, Water and Sustainable use of Pesticides. The environmental media for which there are no comparable Directives are soils and climate. Lengthy discussions have taken place about the necessity for an EU soils Directive, currently this has not been agreed (the Commission's proposal has been withdrawn), and policy action on agricultural soils is therefore left to measures under the Common Agricultural Policy and to national measures in the Member States. This is not necessarily as effective as a new measure could be and there are grounds for further debate. Policy action on climate protection as it affects agriculture is in the process of evolution and needs to be strengthened in line with changes in EU emission targets and policies beyond 2030.

It is generally accepted that the major challenge for European environmental legislation as it relates to agriculture is primarily about whether the current measures are fully implemented and enforced. Given the structural characteristics of the issues and the agricultural sector the enforcement costs of such legislation can be high, so the use of polluter-pays regulations with sanctions for non-compliance is an approach which has not achieved fast results. This is one of the reasons that high hopes have been vested in using quite different approaches to get better adherence to EU environmental directives by using a variety of instruments of the Common Agricultural Policy.

Agricultural Policy. To date, the phrase sustainable intensification has not been adopted as an explicit target or slogan for European agricultural policy. However at the strategic level there is no contradiction between this concept and the current operational objectives of European agricultural and environmental legislation. Environmental and social considerations have steadily grown in importance in the CAP and this is now the largest operational policy for influencing the rural environment as reflected in the number and variety of measures and in the financial resources available to those measures.

The greater integration of environmental and social considerations into the CAP beyond 2013 is quite explicit in the Commission's proposed objectives for the CAP in the communication which launched the negotiations of the most recent reform. These are: viable food production, sustainable management of natural resources and climate action, and balanced rural development. At the level of generality of these concepts they appear compatible with the definition of sustainable intensification suggested in this report. What matters therefore is first, how these general objectives are expressed in measures in the regulations, second on how the measures are selected, interpreted and implemented by the Member States, and finally how they then affect farmer behaviour on the ground. It is suggested that for those parts of EU agriculture not currently on a path of sustainable intensification, the principal problems are weakness at the second and third stages described.

The report summarises the measures under the CAP which have impact an on the environmental performance of farming. These issues have not been under-researched; there is a copious literature describing, analysing and evaluating the measures. They are discussed in the report under the three categories: environmental conditionality, voluntary environmental schemes, and regional, zonal and farm type specific supports. Reference is also made to some market measures such as milk quotas and rural development measures not explicitly environmental, but which can have positive (or indeed negative) environmental effects.

The explicit policy measures in the CAP to bring about improved environmental management of agricultural land have been in place long enough for there to be a growing literature evaluating their effectiveness. This is contained in reports of the Court of Auditors, evaluation reports of the Commission and in the academic literature. The results are mixed. Several reports of the auditors have criticised the objectives and scope of measures as unclear and the legal framework as too complex or poorly enforced. For example, in the case of cross compliance, the auditors found that the Member States did not take their responsibility to implement effective control and sanctions. Other literature provides much evidence of environmental benefits achieved by some of the measures introduced into the CAP. Detailed analysis has revealed many documented examples of improvements for biodiversity and ecosystem services.

The conclusion of this review is that the integration of environment into agricultural policy objectives is relatively secure. In addition, a great deal of ingenuity has been devoted by the Commission, Member States and regions and their stakeholders in devising a wide array of policy measures to integrate better care for the environment into the CAP. If there is an obstacle facing better integration of environment into agricultural practices it is not a lack of imagination of measures to do it. The challenges remain in the practical implementation of these measures, the priority and determination that Member States give to bringing this about, and in the willingness of farmers to constructively engage.

Indications of the political priorities emerged in the negotiation process in the recent reform concerning CAP greening. The Council and Parliament, encouraged by farmers' organisations, diluted the Commission's environmental ambitions in cross compliance and the new greening payments. They evidently judged that ensuring the least impact of the reforms on agricultural production, striving for redistribution of support and simplicity of measures, were stronger imperatives than improving agriculture's environmental performance.

Using supra-national policy to steer the highly complex task of managing the diverse farmed environment of Europe is bound to be a substantial challenge. It is perhaps not at all surprising that it is a task which takes several decades to mature. The integration of environmental management into the Common Agricultural Policy has been underway for approaching a quarter of a century. The process has been slowed and complicated by three factors. First, the continual enlargement of the EU to embrace Members with an ever-greater diversity of environmental, economic and political conditions makes this process more complex and demanding. Second, the task of devising practicable measures which: can be defined in supra-national legislation, implemented on the ground in a way which is in sympathy with normal farming practices, don't disturb competitive conditions, which can be satisfactorily monitored and audited to ensure probity in public expenditure, and also offer cost-effective environmental results has turned out to be a real challenge. Third, this has to be done in a context where those conducting the key management on the ground, the farmers and other land managers, have not been convinced that the 'greening' is a top priority and are not backed by adequate extension services.

This report has concluded that sustainable intensification is a logically correct approach, and that for Europe the emphasis has to be further improvement of the environmental credentials of European agriculture. The 2011-14 reform debate ostensibly gave prominence to the improvement of the sustainability of EU agriculture too, but it is judged not to have advanced very far. What does this indicate for the future?

It is suggested that at the broad policy level the questions now requiring debate should include the following.

- Was the strategy of greening pillar 1 a mistake?
- Has the dilution of greening drained it of impact? Should cross compliance and greening conditions be strengthened?
- If pillar 1 greening payments represent poor value for money, should they be reduced or withdrawn, or should the conditions be significantly tightened?
- Should environmental payments be results-based rather than prescriptive?
- Are the principles which underlie the determination of payment rates for environmental services correct?
- If environmental land management contracts with individual farmers are too expensive and impracticable would it help to operate instead through collectives of farmers at higher, landscape or river catchment scale?
- Is a common European policy for integrating environment into agricultural practice the wrong basis through which to operate, should this be devolved to Member States?
- Are there alternative ways, outside the CAP, for achieving delivery of the environmental services from agriculture? Is more strongly enforced environmental regulation a major part of the answer?

These questions set an agenda for future reforms of the CAP.

The policy section of this report commenced by arguing that to set farmers onto a course of sustainable intensification requires two kinds of collective action: first the establishment and maintenance of a comprehensive evidence base of the state of the rural economy, environment and society, second, the creation of a well-balanced set of policy measures to incentivize and assist farmers to improve their productivity and their environmental performance. It has concluded that the EU has made considerable progress on both of these collective actions. Yet, both are far from complete. There are gaps in the environmental data. Establishing the data for the social sustainability of Europe's rural space is even less developed conceptually and empirically. However perhaps the more important gap is the evidence base on the relationship between specific farming practices and technologies and their environmental impacts.

The main controversy about the CAP remains the balance between the unclearly justified direct payments in Pillar 1 and the more purposeful measures in Pillar 2. But whatever the data and the policy instruments, ultimately, achieving a sustainably intensive EU agricultural sector requires the active participation of its farmers, the subject of the next section.

Actions for farmers and agribusiness

An individual farm, moving towards a path of sustainable intensification will generally have to adjust current practices on their farm so that agricultural productivity improves without detriment to environmental performance, or vice versa. This moves them closer to what can be termed the food-environment production possibilities frontier.

The report discusses five kinds of actions which can be initiated in the private sector.

- The first is the full adoption of one of the many farming systems which have been created specifically for their sustainability attributes.
- Second is to opt for specific farming practices which tackle particular problems of sustainability.
- A third kind of action is to more actively engage in measuring farm-level environmental performance to stimulate and guide action.
- The fourth action is to work collectively or collaboratively in groups of farmers to improve environmental performance.
- The final action considers if significantly higher environmental performance might be brought about through private sustainability certification schemes.

These are considered in turn.

Adopt a system of sustainable farming. Six sustainable systems of farming discussed are: agroecology, biodynamic, organic, integrated and precision farming, and conservation agriculture. Versions of all these systems exist in many EU Member States but the specific permitted and disallowed practices can vary. Of these six farming systems, only organic farming has acquired formal recognition and definition in national and European legislation and internationally. The definition of agroecology is still being debated at present; it covers a wide variety of approaches. Biodynamic farming is a subset of organic farming in which practitioners follow the prescriptions based originally on the lectures of Rudolf Steiner in 1924. Integrated farming is a more recent development.

The first three systems come strongly from the paradigm which asserts the primacy of ecological considerations. They will also generally be associated with mixed, crop and livestock farming. The last two are rooted in what is often referred to as conventional agriculture and the paradigm which puts business viability first. They are comparatively more recent. Conservation agriculture has developed rapidly in the Americas and is based on low-til and no-til farming often associated with the use of genetically modified corn and soya, and also is associated with 'climate smart' agriculture focusing on GHG emissions. Precision farming has arisen in association with the technologies which make use of global positioning satellites (GPS) and information processing of soil mapping and yield data. Integrated farming lies in between the more formulaic first three and the newer technology-inspired last two. It seeks to integrate conventionally efficient farming with much closer attention paid to the impacts on the environment.

In principle, there is nothing to stop any farmer deciding to take up any of these systems. There are few statistics on the uptake of any of them except organic farming – which now accounts for about 4.5% of the EU farmed area. Farmers' decisions will clearly be influenced by their own degree of belief that such a system is necessary or beneficial in relation to their own farming objectives and values. Clearly an important consideration is the economic performance of these systems.

To the extent that the improved environmental performance comes with a penalty of lower or more uncertain yields, or higher costs, not made up in some other way, for example price premia or more assured, perhaps local, markets, this can present an economic obstacle to adoption. At present only organic farming is explicitly recognised in the CAP as deserving of special public support. A risk factor frequently mentioned for conservation agriculture is weed control. A critical consideration for the adoption of precision agriculture is the capital investment required and the necessary scale of operation.

Adopt more sustainable farming practices. Many farmers may not possess the belief, motivation, or investment funds to sign-up to what are thought to be more environmentally sustainable whole farm systems described above. This does not preclude them from making adjustments to their farming operations which move them towards a path of sustainable intensification. Each of the above systems themselves is a combination of individual actions which can improve agricultural productivity and resource efficiency, reduce environmental damage or provide more biodiversity and ecosystem service. The report includes two lists with a total of forty-three such actions covering land-based and livestock management.

What stands out from such compilations is that most of the options are not novel or highly technical. Most do not require large investment, or wholesale change to farming systems. However, the expert judgment behind the assessment of the agricultural productivity impacts of each option indicates that only sixteen of the forty-three options shown are likely to have a positive effect on productivity. The others are likely to have a negative effect or, at best, no effect. It is this uncertainty which perhaps goes some way to explain why the adoption of such practices is limited in most places. Two things which seem to be missing that may provide part of the explanation of why these practices are not more strongly embraced are first that not enough is known and perceived at farm level about the need for them. Second is the question of who bears the costs of adopting such practices. The list of possible answers to this last question is short. It could be the taxpayer if these actions can be paid under publicly funded agri-environment schemes, the consumer if producers can extract a premium price for a more environmentally friendly product, and third the farmer if the adoption of such practices become compulsory through environmental legislation.

Measure then manage. The idea behind this action is the strong contrast between the incentives and benchmarks available for farmers to measure and interpret their economic performance compared to their environmental performance. There are strong incentives, not least from their bank manager, for farmers to measure their economic performance, and there is an extremely well developed set of indicators and benchmarks available to help them interpret what they measure. Neither is true for environmental performance. There is not a strong incentive to do it, and poorly developed benchmarks to help them interpret their own performance. Businesses generally cannot and will not manage what they don't measure.

This action therefore requires some public and private response. It has been suggested that systematic surveys of farms should include more measurement of environmental performance, and in turn as this enables benchmarks to be established and promoted to farmers, they can be incentivised to respond to the information through policy actions.

*Work together with other farmers and stakeholders***.** Many reasons are offered why it could be advantageous to find ways for neighbouring farmers in a catchment or natural area to work together collectively to improve the environmental performance of their activities. One of the most important is that it offers the possibility to find a more ecologically coherent management of a region. It could allow a better alignment between land management decisions and the environmental needs of the whole catchment or landscape. Second, individual farmers may have little interest, knowledge or skills in environmental management. By pooling their efforts those in the neighbourhood with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the environmental expertise can take the lead, or the collective can have the necessary skills bought in. A third area of significant potential gain from collective action is to reduce public transaction costs. In situations of highly fragmented agriculture with large numbers of small farms the administrative costs of setting up, running and monitoring publicly funded agri-environment schemes can be very high. This is especially true if expert environmental advice is required to help design the right scheme for each individual farm. In a collective approach not only does the administrative agency have fewer contracts to attend to, but they effectively decentralize much of the detailed work back to the farm organization. This may also be seen as a benefit to the individual farmers as the planning and execution of the environmental management is negotiated within the farm group between members and employees instead of with officials from a distant bureaucracy. Finally, such collective environmental management arrangements might also lend themselves to greater engagement with local communities and other stakeholders to help establish preferences and priorities for the local environmental and landscape management.

However this approach requires a considerable willingness and trust on the part of farmers to pool decision making with their neighbours. Cooperation and collaboration works extremely well in many Member States, but not in all. There are also many challenges to overcome, for example dealing with non-participants in a natural region, allocating the payments in relation to the environmental contributions, establishing accountability rules and meeting EU requirements dealing with non-compliance, and dealing with farmers who exit a collective arrangement mid-contract. However such are the potential environmental benefits, administrative cost savings and reduction in bureaucracy that these approaches are worthy of greater attention.

*Join enhanced private and agri-business certification schemes***.** The idea behind this action is to persuade, or if it becomes necessary, to require, private sector agribusiness upstream or downstream of farming to enhance the ambitions of private sustainability certification schemes which remain voluntary. The potential advantages are that this could help steer more farmers onto a path of sustainable intensification with improved environmental performance, but do so without the need for public payments or heavy environmental regulation. It would mean that farmers deal more with their business 'partners' up and down stream with whom they have normal commercial relations rather than with bureaucrats.

This approach is easily dismissed by arguments that the private sector is so motivated by short-term profits that they will be unwilling to adopt this approach sufficiently to make a noticeable difference. This seems defeatist. First, many companies surrounding farming are already operating such schemes, some are reviewed in the report. These have ambitions to improve resource efficiency, reduce pollution and increase certain ecosystem services such as pollination. Second, to the extent that parts of EU agriculture, especially those parts which have gone furthest down the intensification path are in danger of approaching environmental limits, then it is in the self-interest of these farmers, their suppliers and buyers to take action. The most intensive sectors of agriculture are also those which are most likely to be in close commercial touch with agri-business.

The critical evidence to judge if commercial certification and sustainability schemes could have a constructive role to help EU agriculture to a sustainable intensification path, is whether they have made any noticeable difference to any aspects of sustainability. Such information does not yet exist. Its collection would require some monitoring of farms enrolled in private certification schemes. This approach would achieve greater public trust and respect if there were some open and transparent monitoring of progress of the performance of participants in the scheme towards aspects of environmental and economic performance.

Case studies

Three case studies were devised to supplement and illustrate this general analysis of sustainable intensification. They were chosen to deal with quite different issues, soils, nutrients and biodiversity, and they employ different analytical approaches.

The first case study, under the direction of Prof Blum of BOKU Vienna, focuses on *soil performance and resilience*. This builds on, and tries to give practical expression to, the idea that managing agriculture towards a development path of sustainable intensification is highly dependent on having sound measurement of the underlying conditions. The study is based on the theory that only fertile soils with specific characteristics have a high resilience against physical, chemical and biological disturbances and also show a high performance capable of supporting the widest range of agricultural commodities if managed safely. Therefore, six specific land and soil characteristics were chosen, (soil organic carbon, clay+silt content, pH, cation exchange capacity, depth and slope). These were combined to define four land classes with respect to their suitability to support sustainable intensification. Data covering two-thirds of the arable area of 25 EU Member States was analysed and it was found that 41% of this area could be classified as suitable for sustainable intensification in the sense adopted in this report. At the other extreme, 4% of this area was defined as not suitable for intensification and indeed should be extensified. The study, of course, explained several important caveats which surround this classification.

The second case study, under the direction of Prof Heissenhuber of Technical University Munich, is concerned with nutrient management. This deals with a well-acknowledged problem of European intensive livestock production; its association with a chronic problem of nutrient surplus, principally nitrogen and phosphorus, on agricultural soils. This case study probes some alternative ways of dealing with this regional imbalance of nutrients. It tries to do so by starting from the broad perspective, which juxtaposes the nutrient excess intensive livestock and urban areas with the nutrient deficit cropping areas. In this perspective it makes sense to consider how the excess nutrients can be recovered from the surplus regions (animal manure and sewage sludge) and recycled to the deficit regions. This case study offers some preliminary calculations to illustrate the kinds of analysis which can shed light on this question. The balance to be struck is to reduce the livestock density, and thus the manure output, to that which can be economically distributed and utilized by crops in the surrounding area. Finding this balance, in turn, requires knowledge of the relative economies of scale in animal production and the costs of processing and transporting the manure. A methodology for investigating these calculations is illustrated for dairy production, and similar calculations have been carried out for pig production. Early results indicate that the optimal scale of production is likely to be smaller and more sensitive to herd size if manure has to be transported over longer distances. This case study offered a different perspective on actions which can be seen as consistent with the proposed definition of sustainable intensification.

The third case study, also directed by Prof Heissenhuber, focuses on ways of looking at biodiversity and how it can be better managed in arable farming areas. This study considers the extent to which biodiversity and agricultural productivity have to be traded-off against each other or whether there are sustainable intensification pathways which offer opportunities to improve both together. The study gives particular emphasis to spatial-temporal considerations in defining the appropriate conservation measures for biodiversity, and how these will be heavily conditioned by the presence or absence of structural elements, e.g. hedges, trees and water courses, in the rural landscape.

A particularly revealing aspect of the biodiversity study was the empirical data on the variability of yield and biodiversity combinations discovered in arable fields in Germany, Netherlands, Spain and Poland. This provided neat evidence that the generally observed wide differences in economic performance on farms, is matched and perhaps exceeded, by the variability in environmental performance of individual farms (or fields). This is revealed in data presented in the case study on biodiversity. The importance of this observation is that it implies that much agricultural production in Europe may be taking place well inside the food-environment production possibilities frontier. This in turn implies that there may be corresponding scope to achieve gains from sustainable intensification which moves farm (and field) management closer to the frontier.

Final remarks

This report has argued that it is the sustainability aspect of sustainable intensification which requires most attention in the European Union. It has been further argued that within the broad concept of sustainability, the environmental dimension requires more attention than the other pillars. The collective action required to define and measure the environmental performance of agriculture is well advanced, although not complete. However enough data already exists to pinpoint where biodiversity, soil, water, climate and landscape management are not adequate to achieve the standards set in EU legislation. This is well exemplified in the first case study included in the report. Equally, the suite of policies to protect the farmed environment through environmental legislation and agricultural policy instruments is well developed. In short, in Europe, broadly we know what the problems are and where they are, and we have policy measures which could contribute to dealing with them, so why is progress to reduce these problems insufficient?

One answer is a misguided concern of the contribution of European agricultural production to global food security. The worry is that by taking measures to improve environmental performance in Europe this will reduce production potential in a world of still growing population and food demand. These fears are exaggerated. Europe is a relatively high cost production area and its agricultural exports are of more processed high quality foods and highly developed plant and animal genetics. It is therefore not generally a source of low cost calories for poorest countries. Second, recent econometric analysis of European output and productivity growth concluded that Europe's output growth has indeed slowed over several decades but this slowdown in "is entirely due to withdrawals of resources from agriculture especially labour, and not to a slowdown in productivity growth". There is a continuing long-term trend in underlying productivity growth which, in turn, responds positively to R&D efforts. In this context the potential output loss from the further withdrawal of a few percentage points of land to provide biodiversity and water protection could be replaced by a relatively few year's productivity growth. Third, such is the size of food waste in the EU, that the private and public efforts to reduce this could also 'replace' output forgone from some production areas where actions are taken to reduce negative environmental effects of intensive production.

Another answer lies perhaps with the perceptions and motivations of farmers. It is not at all clear that they appreciate the extent of the environmental degradation that has accumulated over the last century, or the potential threat this poses for continued future production. This underlines the importance of continuing the efforts to provide the evidence of this damage, and to put more effort to investigate the extent of environmental change and to improve our understanding of the timescale in which environmental thresholds may be reached.

The two most important lessons of applying the idea of sustainable intensification to European agriculture are that farmers and the public should learn to take a more holistic view of the agricultural and environmental outputs from agricultural land management, and that the key input to be intensified is knowledge.

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