Sustainable intensification revisited

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Sustainable intensification is receiving growing attention as a way to address the challenge of feeding an increasingly populous and resource-constrained world. But are we asking too much of it? Nearly 20 years after the concept was developed, this paper revisits the term and proposes what sustainable intensification is – a useful guiding framework for raising agricultural productivity on existing arable land in a sustainable manner; and what it is not – a paradigm for achieving food security overall. The paper summarises the history of and controversy surrounding the term, its main assumptions and risks, as well as its value for the future. We call for a re-rooting of sustainable intensification as one key element of a sustainable food system situated within a green economy.

Contents

Executive summary

Claims that we need to produce significantly more food by 2050 are common in both the media and the academic literature, spurring schemes to intensify agriculture in developing countries where agricultural productivity is low. The sustainable intensification of agriculture is increasingly being seen as the answer by many high-profile agriculture, food security and development bodies. But what does it mean, and can it deliver?

While the term sustainable intensification has been in existence for two decades, its use has only recently become mainstream. It was originally conceived as an approach to produce higher levels of output from the same area of land while decreasing the negative environmental impacts of agricultural production and increasing the provision of environmental services. While few would dispute the need to boost food production in sustainable ways or to increase resource use efficiency, there are troubling aspects to the way the term is currently being used by some. Sustainable intensification is now coming under severe criticism from NGOs working on agriculture and food security. So what are the risks with current usage of the term?

- Some actors are using sustainable intensification to justify a repackaging of intensive, high-input models and the use of proprietary technologies, such as biotechnology, as the means to achieve it.
- While agroecology as well as genetics are proposed as means to increase productivity, very little money actually goes to developing and scaling out agroecological practices.
- Sustainability is often defined too narrowly, neglecting its vital social and economic elements, for example, livelihoods, equity, social justice and economic viability.
- An exclusive focus on crop production risks not addressing the farming system as a whole, including livestock, which is a necessity for achieving food security.

This paper sifts through these debates, unpacks the assumptions and terminology behind sustainable intensification as well as its use by different players, and inquires whether or under what conditions it can offer positive contributions to debates on the future of agriculture and food security and serve as a framework for increasing both productivity and sustainability.

Unpacking the concept

The prominence of sustainable intensification in current debates is based upon three fundamental assumptions about food security and agricultural production in the 21st century:

1) The world needs to produce significantly more food in the coming decades to feed a growing, increasingly affluent population.
2) The arable land base cannot be expanded significantly.
3) Agricultural production must become more sustainable and resource use efficient in order to preserve the natural capital on which agriculture relies.

Considered together, these three assumptions imply that agricultural production on existing arable land must intensify in order to meet higher demand, but in a manner which does not damage the environment. We believe that the latter two assumptions are sound, but the first requires some qualification.

The assumption that feeding people is always about producing more food ignores the evidence that hunger is often more an issue of access and entitlement to food rather than its total availability. Despite plentiful supplies of food globally, more than 800 million people remain hungry today and one-third of the global population suffers from micronutrient deficiencies. Thus, producing more food is no guarantee of worldwide food security, particularly for people suffering from deprivation.

While the demand for food is likely to increase significantly due to population growth, rising affluence and changing food consumption patterns, estimates vary hugely of how much additional food will be required in the future. Projections of future food demand typically assume the continuation of current trends, neglecting to take into account how changes in rates of population growth, urbanisation, affluence, consumption patterns, food waste, biofuel demand, etc. would affect the demand for food and its availability.

Re-rooting sustainable intensification in the food system

Because food production is only one factor contributing to food security, we propose to consider sustainable intensification within a wider sustainable food system. 'Food system' is a fundamental concept in this paper, but what does it mean? We use it to encompass "… the people and resources involved in producing, processing, distributing and consuming food and managing waste…[it] operates within social, political, economic and environmental contexts".

Provided it is properly defined and contextualised, sustainable intensification can be a useful framework for addressing one critical aspect of the global food system in the 21st century, namely agricultural production (Figure 1). However, it is not an all-encompassing paradigm designed to address all aspects of the food system.

Sustainable intensification should be treated as one component within a larger food systems perspective which includes efforts on multiple fronts to promote food security by bolstering property rights for farmers and ensuring access to food for vulnerable groups, limiting food waste, stemming population growth, curbing demand (particularly for meat and dairy products), preserving agricultural land, and meeting the energy needs of smallholders while limiting fossil fuel intensity.

The next step will be to develop clear criteria for carrying the sustainable intensification concept forward in individual countries through multi-stakeholder dialogue involving representatives of food insecure/vulnerable groups and building upon local knowledge and priorities. These criteria should give at least equal weighting to sustainability issues (including livelihoods, social justice, economic viability and environmental soundness) as to intensification. They should also reflect the fact that sustainable intensification can only address food production (as one component of a global food system perspective); other approaches will be needed to tackle consumption and waste, access and entitlements, markets and power.

While the most appropriate measures will tend to vary by locality, there are some general principles that can guide policies and initiatives designed to sustainably intensify agricultural production:

- Provide incentives to drastically reduce the environmental impacts of crop and livestock production
- Promote low-cost approaches for sustainably raising agricultural productivity which farmers can control
- Enable and invest in local innovation and adaptation using both local/traditional knowledge and science
- Recognise the important role of public sector funding for agricultural research, given that sustainable intensification will entail reduced use of external inputs in many regions and therefore reduced incentives for private-sector involvement.
- Discourage the use of highly productive croplands to grow animal feed
- Address the energy needs of smallholders while limiting fossil fuel intensity and reducing GHG emissions
- Strengthen the voice of smallholders and vulnerable groups in decisions about agriculture and land use.
- Focus on enhancing the economic value of farming as well as its productivity.

Food security is a complex and multifaceted issue for which there are no silver bullets. An integrated approach is needed, as action is required on all fronts. Sustainable intensification is a useful guiding framework for addressing one key component of the food system – namely food production. It is not an adequate framework for addressing food security overall. That requires nothing less than a food system perspective situated within the larger context of a green economy.

Sustainable intensification: then and now

Sustainable intensification involves increasing output levels from the same area of land while decreasing the negative environmental impacts of agricultural production and increasing the provision of environmental services. While this definition seems innocuous enough, sustainable intensification has become a controversial term. For proponents, it is a promising new paradigm to guide agriculture in an era of burgeoning food demand and resource scarcity. For detractors, it is an oxymoron – an excuse for perpetuating the current corporate model of intensive farming with a sugar coating of sustainability.

1

Sustainable intensification has received growing attention as a framework to address the challenge of feeding an increasingly populous and resource-constrained world. The origins of the term stretch back nearly 20 years, but it has come into vogue in the last five years through the publication of a series of high-level reports by influential institutions. Today the concept is a contested one, with the controversies stemming principally from the use of the term by different actors, their respective underlying interests and values, as well as assumptions about the scope of issues it can address within the wider food system.

While few would dispute the need to boost food production in sustainable ways or to increase resource use efficiency, there are troubling aspects to the way the term is currently being used. The first is the likelihood that intensification will overshadow sustainability, meaning that current trends favouring the promotion of high external input agriculture will continue, albeit in a slightly more palatable guise. Second, there is a danger of sustainability being defined too narrowly - i.e. solely in terms of resource efficiency and neglecting its vital social and economic elements (e.g. social justice, equity, livelihoods and economic viability). Discussions thus far have focused primarily on technical solutions while neglecting social and political considerations, which are critical because the implementation of the concept needs to be determined in different contexts with local stakeholders rather than by external agents. Third, the absence of a food system perspective in much of the sustainable intensification literature has led to an exclusive focus on crop production, whereas food security requires addressing the farming system as a whole, including livestock, within a broader food systems perspective. Are these problems inherent in the concept or rather a function of how it has been used thus far?

With these issues in mind, this paper critically examines the concept of sustainable intensification, its origins and uses by different players, and asks whether or under what conditions it can offer positive contributions to debates on the future of agriculture and food security (Box 1). Our intention here is to open up debate about the range of uses to which this term has been put, to show how it is related to other concepts, and to provide recommendations on the place of sustainable intensification within a larger food system. We conclude that sustainable intensification can serve as a useful guiding framework for addressing one critical aspect of the global food system in the 21st century, namely food production. However, it is not a comprehensive paradigm for addressing food security, and other approaches will be needed to tackle consumption and waste, access and entitlements, markets and distribution. Food security requires that all facets of the food system be addressed simultaneously, along with factors such as land use, energy and population dynamics.

'Food system' is a fundamental concept in this paper, but what does it mean? We use it to encompass "… the people and resources involved in producing, processing, distributing and consuming food and managing waste…[it] operates within social, political, economic and environmental contexts"[1]

BOX 1. APPROACH

In researching this paper we looked at over 60 reports and articles that address sustainable intensification in one way or another in order to assess how each author and organisation uses the term. The document review revealed significant discrepancies in interpretations of the concept and the extent to which it is believed to address wider food security[2] issues. As the term is ubiquitous today in national and international discussions around agricultural development and food security, it is important to understand how it has been interpreted and critiqued by different actors.

1.1 The origins of sustainable intensification

Sustainable intensification has been defined by the British scientific institution the Royal Society as a process whereby "yields are increased without adverse environmental impacts and without the cultivation of more land".[3] It refers to simultaneous increases in output per unit area, resource use efficiency, natural capital and the flow of environmental services, and reductions in negative environmental impacts, such as greenhouse gas emissions.[4, 5, 6]

This definition of sustainable intensification has been widely cited. However, it is worth noting that use of the term in the literature is not entirely consistent. Some reports tend to use sustainable intensification and sustainable agriculture interchangeably.[7] Others use a slightly different term, such as sustainable crop production intensification, thus limiting it to the crop sub-sector.[8] Related concepts such as ecological intensification and agroecology are discussed in Box 2.

To shed light on current debates around sustainable intensification, the first step is to retrace its roots. The term was originally coined in the 1990s in the context of smallholder agriculture in Africa,[9,10] where productivity was predominantly low and degradation of natural resources a major concern. Population growth meant that previous patterns of extensive production by bringing new land under cultivation were no longer viable, and that African farmers needed instead to meet rising demand for food and fibre by intensifying production on existing arable land.[11] This was to be done by investing more labour and inputs (e.g. fertiliser) in a given area of land to raise yields. Whereas previous forms of intensification had depleted soils through shorter fallow periods and denser planting, what was also needed were soil conservation measures such as bunds, windbreaks, terraces and agroforestry to control soil erosion and loss of soil fertility. This model aimed to use "inputs and capital which provide net gains in productivity, but which also protect land and water, and enhance soil fertility over time."[12]

Echoing the debates of today, advocates of sustainable intensification at the time argued that it was indeed possible to substantially raise yields of smallholders in developing countries, and to do so in ways which did not degrade the arable land base. This would require a departure from standard top-down approaches as well as high-input models of agriculture:

… substantial growth is possible in currently unimproved or degraded areas whilst at the same time protecting or even regenerating natural resources. Those advocating 'sustainable intensification' point to recent empirical evidence … to argue that low-input (but not necessarily zero-input) agriculture can be highly productive, provided farmers participate fully in all stages of technology development and extension. They maintain that this evidence indicates that changes in the productivity of agricultural and pastoral lands is as much a function of human capacity and ingenuity as it is of biological and physical processes.[13]

There are several features worth noting about these early studies. First, all of them focused on smallholder production in the developing world (particularly Africa), and took a decidedly pro-smallholder stance. This contrasts with later interpretations, in which sustainable intensification has come to be treated as a framework for agricultural production at a global level. Second, the original conception of sustainable intensification placed equal emphasis on sustainability and intensification; in fact, sustainability was seen as a prerequisite for intensification given the degraded state of many agricultural lands in Africa and other regions. Third, there was an emphasis on flexibility and the need to adapt approaches to local context, rather than prescribing a fixed set of agricultural practices. Fourth, enhancing farmers' livelihoods was a central goal of sustainable intensification.

1.2 Use of the concept today

In spite of its origins nearly two decades ago, it has only been in the last five years or so that sustainable intensification has gained prominence as a concept. In this time it has been endorsed by governments such as the UK,[14] the US[15] and the African Union[16]; international institutions such as FAO[17] and IFAD[18]; research institutions including the Consultative Group on International Agricultural Research (CGIAR)[19] and its 15 research centres; agribusiness companies and organisations such as the International Fertilizer Industry Association[20] and the Agricultural Biotechnology Council[21]; and foundations such as the Bill and Melinda Gates Foundation[22].

Today sustainable intensification is not simply applied to Africa but to regions throughout the world. In fact, it has become a priority theme that repeatedly arises in international conferences and agricultural development planning. Three high-end drivers have been particularly instrumental in elevating the term from its historical African roots to a prominent place in international discussions on agriculture:

1. The Royal Society report *Reaping the Benefits* (2009).
2. The adoption of 'the Sustainable Intensification of Crop Production' as Priority Objective A by the United Nations Food and Agriculture Organisation (FAO) in 2010.
3. The UK government's *Foresight Report on the Future of Food and Farming* in 2011.

All three highlight the need for increased productivity and sustainability in global food production, and promote sustainable intensification as a framework for achieving these dual goals.

The Royal Society and Foresight reports have been very influential and have much in common. Both are measured in tone, and take an optimistic view of what the latest biological science advances in genomics and other fields can offer to feed the world's growing population. Both reports define sustainability in a broad sense – heavy on environmental aspects while still including some social and economic dimensions – although neither include equity nor social justice therein. The approach taken in both cases is inclusive – encompassing agroecological crop and soil management practices (Box 2) as well as new crop varieties and biotechnology – with the view that no practice should be ruled out. This is justified by the "perfect storm" scenario[23] painted by the then-UK chief scientist John Beddington. The "perfect storm" has since been used to support a crisis narrative that emphasises the urgency to increase food production by all possible means.[24]

The authors point out that there are invariably trade-offs and local complexities, and that the challenges of agriculture require a diversity of approaches. Thus sustainable intensification is taken as a goal rather than a prescription for the adoption of a particular type of farming system. One key difference between these two reports is that although the Royal Society report offers "a tight focus on the possible contributions of biological science and technology"[25] to food production – while making only brief mention of other aspects of the food system (e.g. access to food, consumption, waste and markets), the Foresight report deals explicitly with issues beyond production, including the causes of hunger and measures needed to address it.

A notable contribution to the literature was made in a report by Garnett and Godfray[26], based on a workshop organized by the Food Climate Research Network and the Oxford Martin Programme on the Future of Food. The report takes a systems approach to examining the issues and challenges surrounding sustainable intensification, with particular focus on three areas: sustainability, animal welfare and nutrition. Garnett and Godfray[27] contend that sustainable intensification "is best envisaged as a pragmatic process of enquiry and analysis for navigating the issues and concerns" surrounding agricultural production. The authors argue that sustainable intensification is still a useful framework in spite of its contentious status today, and that replacing it with a different term would not resolve the underlying differences in values, perspectives and interests which lie at the heart of the debates surrounding the term. They note that competing paradigms "all will have to engage with the reality that there are hard trade-offs between different desirable outcomes and uncomfortable choices for all stakeholders whatever their prior beliefs."[28] The report is notable for its balance, integral approach and dispassionate analysis of many of the fundamental issues underlying sustainable intensification.

By no means are all treatments of sustainable intensification so balanced, nuanced or disinterested, however. Sustainable intensification has also been adopted by multinational agri-food companies, as a means to promote their products, and has tended to be defined more selectively. As the Agricultural Biotechnology Council, an umbrella group for the agricultural biotechnology industry in the UK puts it, "this process of growing more food, with lower inputs, and without more land is known as sustainable intensification. Agricultural technologies, such as GM, are among the tools which can help to deliver sustainable intensification…"[29] Thus the conception of sustainability is extremely narrow – limited to lower inputs – and there are clear preferences as to the techniques to be promoted. In this context, the crisis narrative emerging from the "Perfect Storm" scenario is increasingly used by agribusiness to justify inclusion of biotechnological and high external input solutions to increase yields.

A similar treatment is evident in the International Fertilizer Industry Association's endorsement of the concept, according to which promoting greater uptake of inputs such as chemical fertilizer becomes the means of closing the yield gap between farmers in the developed and developing world.[30] In these terms, sustainable intensification is a useful avenue for augmenting business opportunities, as it is being interpreted solely as intensification.[31] A focus on raising levels of fertiliser use in sub-Saharan Africa requires parallel attention to the highly damaging over-use of chemical fertiliser in most other parts of the world.

A key point of divergence in the literature is whether sustainable intensification represents an end goal in itself or a description of the means to that goal. The agribusiness industry tends towards the latter approach, in that a particular model of agriculture (as represented by certain inputs and technologies) is favoured. This is understandable, given that it is clearly in the interests of agribusiness to sell more of their products, and a narrative focused on the need to produce significantly more food in the coming decades serves that purpose well.

By contrast, the Royal Society and Foresight reports take a less prescriptive approach. Similarly, the report by the Oxford Martin Programme for the Future of Food envisions sustainable intensification as "a framework for exploring what mix of approaches might work best based on the existing biophysical, social, cultural and economic context…"[32] This emphasis on flexibility and local specificity is reminiscent of the original conception of the term by Jules Pretty and others, who envisioned it as a process of learning and adaptation that is not constrained by specific technologies, practices or policies. According to this vision, farmers and farming communities can therefore adapt as knowledge changes and are not restricted in their future options.[33] While the open-endedness that characterises the Royal Society and Foresight reports is an asset in one sense, it is also potentially problematic if it leaves the door open to the continuation of high-input conventional approaches, or to policies which have negative impacts upon the access to and distribution of land and food at the local level.

1.3 Critiques of sustainable intensification

Given the varying definitions and uses of the term by different actors, it is hardly surprising that sustainable intensification has been heavily criticised – specifically its use in recent years by international organisations, western governments, research institutions and agribusiness companies, rather than the way it was originally conceived. Chief among its critics are non-governmental organisations working on agriculture and food security. Their main criticisms are that current interpretations of sustainable intensification:

1) reflect a productivist agenda which privileges production (supply) over other aspects of food security (e.g. access and distribution)
2) are based upon a framing of resource scarcity, but lack social and political analysis
3) essentially represent a continuation of current, high external-input approaches, but with a sugar coating of sustainability
4) favour technological approaches while devoting few resources to lower cost agroecological methods
5) focus exclusively on crop production rather than addressing the farming system as a whole, including livestock, which is a necessity for achieving food security
6) involve a co-option of agroecology, ignoring its social and political dimensions (Box 2)
7) define sustainability too narrowly, neglecting its vital social and economic elements, for example, livelihoods, equity, social justice and economic viability
8) aim to bolster a corporate-dominated food system rather than transform it.

Let's look in more detail at the concerns raised about sustainable intensification. These are some of the key themes arising repeatedly in critiques of the term:

Justification of intensive, high-input models

Some actors are using sustainable intensification to justify a repackaging of intensive, high-input models of agriculture. The perceived danger is that sustainable intensification as promoted by powerful agribusiness interests would essentially result in a continuation of the status quo (promotion of high external input models) with a 'sugar coating' of sustainability. As Jonathan Porritt of Forum for the Future observes:

Given its provenance (in a Foresight Report on the future of food and farming), I was at first inclined to give the 'sustainable intensification' terminology the benefit of the doubt. That was naïve. It's quite clear, two years on, that the idea of sustainable intensification is being used by big farming interests and agrochemical companies to describe exactly the same old model of intensive farming, linguistically (and dishonestly) embellished with the 's' word.[34]

From this point of view, sustainable intensification does not represent a fundamentally new approach, but rather a repackaging of intensive, Green Revolution models in a somewhat adjusted form. As Collins and Chandrasekaran put it, "in practice it can mean business-as-usual intensive farming with slight modifications to try and tackle the growing environmental crises caused by industrial agriculture."[35]

An excuse to ignore contentious issues of consumption

Another critique that has been made of sustainable intensification is that it provides an excuse for governments and other actors to ignore contentious issues of consumption. By providing a win-win scenario in which yields can be increased sustainably on the same amount of land, there is little need to address unsustainable levels of demand for meat, dairy and other resource intensive products among wealthier segments of the global population.[36] It is noteworthy that few articles situate sustainable intensification within a larger food systems perspective. This may be because discussion of other aspects of the food system – particularly factors which might reduce demand for food or guarantee food access for the poor – does not serve certain interests as well as an exclusive focus on production and productivity. Moreover, measures to reduce consumption – particularly of resource-intensive meat and dairy products – are broadly unpopular not just in rich countries, but also among the middle classes in developing and emerging economies as well (who may be particularly sensitive to the promotion of 'sustainable consumption' from the wealthier 'developed' countries, whose consumption patterns are currently still much less sustainable). Measures to curtail consumption are also unpopular because they are perceived as being contrary to promoting economic growth.

Use of scarcity arguments lacking in social and political analysis

One concern that has been raised is that treatments of sustainable intensification focusing solely on the need for increased production are often based upon a generic, apolitical conception of resource scarcity. Narratives on resource scarcity have long been used to justify the acquisition of resources deemed to be 'under-utilised', but which may actually be common property resources that are fundamental for food security, such as communally-owned traditional grazing lands in semi-arid areas.

Caution is merited "when proclaiming generic resource scarcity as a driving force for action. My scarcity may be someone else's surplus: scarcities are always relative, and resource access and distribution is a crucial issue that is not addressed by this narrative"[37] (see Box 3). Furthermore, the dearth of social and political analysis in current treatments of sustainable intensification is problematic in that it "may restrict debate about alternative choices, and debates about pros, cons, risks and rewards."[38] This in turn could lead to fewer options for farmers and for society as a whole.

An open door to all technologies?

Another common criticism of recent usage of sustainable intensification is that it is open to all types of technology as the means to achieve it. This enables some companies and scientists to promote proprietary technologies such as biotechnology, which are seen by many organisations active on food system issues as being fundamentally incompatible with sustainability.[39] However, Hird (2012) makes the case that there is no reason to choose biotechnology "when there are so many technologies and practices to choose from to increase yields sustainably".[40] A related critique is that while actors promoting sustainable intensification espouse both agreocology (Box 2) and genetic means to increase productivity, very little money actually goes to agroecological research and development. As Hird observes, "one could argue that funding and political attention is prioritised on GM, where major profits can be made, when cheaper and simpler alternatives are already delivering."[41]

Finally, Holt-Giménez and Altieri[42] argue that ecological aspects of agroecology are being selectively adopted by those who seek to promote a new Green Revolution, while preserving the current corporate-dominated food system and neoliberal economic model. Seen in this way, sustainable intensification is a reformist approach rather than a transformative one.[43] In their view, what is needed is to closely link agroecology with food sovereignty so as to transform the global food system in a way which would better serve the livelihoods of smallholders, alleviate hunger and conserve agroecosystems. It is important to note, however, that there are different treatments of agroecology in the literature, and that by no means all of them conceive of agroecology as a political movement (Box 2).

BOX 2. AGROECOLOGY, ECOLOGICAL INTENSIFICATION AND SUSTAINABLE INTENSIFICATION COMPARED

Agroecology has been defined as "the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems".[44] First appearing in the scientific literature in the 1930s, today the term may refer either to a scientific discipline, a set of agricultural practices, or a social movement,[45] with the consequence that it often means different things to different actors.[46] For instance, in the sustainable intensification literature, agroecological farming practices - such as intercropping and poly-cultures, crop rotations and fallowing, crop-livestock integration, biological management of pests, efficient water harvesting, agro-forestry, composting and waste recycling – are frequently mentioned as a means to help smallholder farmers to sustainably intensify their production.[47] However, others stress that agroecological approaches should be primarily concerned with maximizing ecosystem services, rather than agricultural production. Agroecological movements, on the other hand, look beyond the interaction between farming and ecosystems, and emphasise other issues such as equity, the preservation of indigenous knowledge, food sovereignty and the sustainability of local food systems.[48]

Some recent reports reconcile these different visions, presenting agroecology as an alternative to (and sometimes in sharp contrast with) some of the narrower definitions of sustainable intensification.[49] Although there are differences in the scope and the objectives of these studies, their underlying message is that, in order to preserve the ecological foundations of food security, a paradigm shift is needed towards multi-functional agriculture. Under this new paradigm, the 'non-commodity' outputs of agriculture (such as agro-biodiversity, ecosystem services, landscape amenities and cultural heritage) are valued as much as its commodity outputs. Agroecology is thus conceived as a means to *re-orient* rather than to *intensify* agricultural production, where the achievement of stable ecosystem functions and optimisation in the use of resources are prioritised over the maximisation of yields.

Ecological intensification "has generally been considered to be based essentially on the use of biological regulation to manage agroecosystems, at field, farm and landscape scales."[50] The 2013 Montpellier Panel Report treats ecological intensification as one component of sustainable intensification alongside genetic intensification and socioeconomic intensification. The report refers to ecological intensification as the application of agroecological processes to the improvement of cropping systems through techniques such as inter-cropping, agroforestry, Integrated Pest Management, and conservation agriculture.[51]

However, the concept of ecological intensification is also used outside and sometimes in opposition to the sustainable intensification narrative. According to Tittonell,[52] ecological intensification is more strongly associated in the literature with concepts such as 'landscape and ecosystem approaches', 'biodiversity', 'ecosystem services', and 'agroecology', whereas sustainable intensification is more closely associated with 'resource use efficiency', 'eco-efficiency', 'technology' and 'precision agriculture'. In other words, the proponents of sustainable intensification focus on maximising crop yields while minimizing the environmental impacts of agriculture, whereas ecological intensification aims at maximizing the ecosystem services delivered by the farming sector, adapting the productive potential to the physical limits of the surrounding landscape. Tittonell also notes that in ecological intensification "the role of local resources and indigenous knowledge is also recognised, so that farmers are not mere adopters of technologies; they generate locally adapted knowledge and technologies."[53] Finally, there are key differences in the actors espousing these two concepts. Whereas sustainable intensification has been endorsed by many powerful international institutions, foundations and agribusiness, ecological intensification is favoured by certain academics, NGOs and grassroots movements.

Unpacking the concept

Debates surrounding sustainable intensification stem partly from some of the fundamental assumptions about food and agriculture in the 21st century. Chief among these is the assumption that the world needs to produce significantly more food, without always considering how changes in parameters such as access, demand, waste and consumption may alter the equation. Other sources of debate are the way in which the terms 'sustainable' and 'intensification' are interpreted.

2

2.1 Probing the assumptions

The concept of sustainable intensification – as used by most actors today – is based upon three fundamental assumptions about agricultural production systems in the 21st century:

1) The world needs to produce significantly more food[54] in the coming decades to feed a growing, increasingly affluent and urbanised population.
2) The arable land base cannot be expanded significantly.
3) Agricultural production must become more sustainable and resource-efficient in order to preserve the natural capital on which it relies.

Considered together, these three assumptions imply that agricultural production on existing arable land must intensify in order to meet higher demand, but in a manner which does not damage the environment. All three of these assumptions need to be examined one by one.

First and most controversial is the perceived need to drastically increase production. Although increasing demand for food will inevitably play a role in shaping what sustainable intensification will look like in practice, the term was not originally framed as a way to meet specific production targets.[55] The underlying idea behind sustainable intensification is that regardless of demand and production levels we still need to optimise productivity, and make our food production systems more sustainable and resource-efficient in order to maintain agricultural systems over time, to restore degraded land, and to alleviate existing threats to biodiversity and ecosystem services by not expanding arable land.

It is also important to recognise that projections of future food demand typically assume the continuation of current trends. They often neglect to take into account how efforts to reduce waste and demand for resource-intensive animal products, and to improve food access, may alter the figures (Box 3). If we interpret sustainable intensification solely in terms of meeting demand for increased production, there is

BOX 3: MORE FOOD, OR BETTER ACCESS TO FOOD?

Claims that we need to produce significantly more food by 2050 are common in both the media and the academic literature, spurring schemes to intensify agriculture in developing countries where agricultural productivity is low. Figures generally range from a 60–110% increase in total agricultural output by 2050. But on what basis are these claims made?

The commonly quoted figure of the need for a 70% increase in food production by 2050 originates with the FAO.[56] In 2012, the FAO revised this figure down to 60%.[57] These figures are based on projections for production and consumption (from the three-year average of 2005–2007), which in turn are based on projections for population and income, complemented with assumptions about changing demand patterns, yield growth and land availability. The original projection for a 70% increase in production was revised down to 60% in 2012 due to updated data showing that "production in 2005/2007 was actually significantly higher than previously estimated, particularly in developing countries. By contrast, projected 2050 levels remain essentially unchanged."[58]

Tilman *et al.* (2011) estimate that global demand for food crops will increase by 100–110% between 2005 and 2050.[59] Foley *et al.* (2011) note that "recent studies suggest that production would need to roughly double to keep pace with projected demands from population growth, dietary changes (especially meat consumption), and increasing bioenergy use, unless there are dramatic changes in agricultural consumption patterns."[60]

At the same time, critics of the current food system point out that there is more than enough food available today to provide every human being on the planet with an adequate diet, but that poverty and unequal access to food are the sources of chronic hunger plaguing more than 800 million people.[61] Seen in that light, what is required to address hunger is not so much increases in production, as better distribution and access to food for all.[62] Of course, it is important to distinguish between hunger, and rising future demand for food. While there is enough food being produced now to feed all, this will not necessarily be the case in the future as demand rises substantially. What is clear is that unless distributional, political and economic issues in the food system are addressed, there is no guarantee that higher levels of production will mean more people are food secure.

a danger that intensification will be prioritised over sustainability, which may lead to preferential investment in high-cost technologies over more low-cost alternative methods. An exclusive focus on increasing production and productivity may simply increase waste, losses and consumption, providing little benefit to the food insecure, and doing little to rectify current imbalances in the food system.

The second assumption concerns the arable land base. In many parts of the world, there is little potential to bring new land into production. As the FAO publication *Save and Grow*[63] puts it:

In most developing countries, there is little room for expansion of arable land. Virtually no spare land is available in South Asia and the Near East/North Africa. Where land is available, in sub-Saharan Africa and Latin America, more than 70 percent suffers from soil and terrain constraints. Between 2015 and 2030, therefore, an estimated 80 percent of the required food production increases will have to come from intensification in the form of yield increases and higher cropping intensities.

In fact, an equally daunting challenge is how to preserve existing arable land from development for residential complexes, shopping centres, industrial parks, roads, dams, mines and a host of other uses. There are also the problems of the substantial release of greenhouse gases through land conversion and the detrimental effects of ecosystem degradation on biodiversity and ecosystem services. There is, however, still debate over how existing agricultural land should be managed in a way that best mitigates these threats.

Third, is the imperative for greater sustainability. Erosion, loss of soil fertility, pollution from agrochemicals, depletion of groundwater, among other factors, are undermining the ability of the arable land base to support current and future agricultural production. While the need for greater resource-use efficiency and sustainability is clear, the methods and extent to which these can be achieved remain disputed. Sustainability can be viewed at multiple levels, from the level of the field to the landscape, to the ecological, economic, social and cultural sustainability of the global food system. There remains a lack of clarity in the literature as to whether sustainable intensification should refer purely to the ecological sustainability of production methods or whether all dimensions of sustainability (e.g. social, economic) and other areas of the food system should be integrated from the outset. This terminology dilemma is discussed in the section which follows.

One common feature of the academic and policy studies on the future demand for food is that they focus on the production side of the equation, and tend to assume the continuation of current trends in population growth, income and the convergence of dietary preferences in developing countries with those of developed countries. Little attention is paid to the potential for influencing the demand side of the equation, including biofuels, meat and dairy consumption, and food waste, or to the potential for increasing access to food for the more than 800 million people who are currently hungry[64] despite the fact that enough food is produced for all. This means that, if effective measures could be taken to cut demand, reduce waste and improve food access and distribution, the need for increased production could also be curtailed.[65] Furthermore, given the wide discrepancy in the various estimates for future food demand, there is ample scope for questioning their reliability as a basis for policy. It is also clear that framings of the food security debate which focus on the need to drastically increase production serve certain interests while marginalising other framings which focus on hunger, equity and access to food.[66]

It is understandable that prescriptions for global food security tend to focus on production. The international organizations and research institutes working on food issues are institutionally better prepared to cope with production than to tackle broader problems such as consumption, waste, governance and inequities in the distribution of food. Meanwhile, it is clearly in the interests of agribusiness companies to frame issues surrounding food security in terms of the need for ever greater supplies, just as they have little to gain from approaches which promote greater economy in the use of inputs. Addressing challenges in the wider food systems context is also more politically and socially sensitive than just increasing production. Challenging consumption patterns is controversial. A consensus is far easier to achieve around producing more food.

2.2 Analysing the terminology

Much of the controversy surrounding sustainable intensification stems from issues with terminology and differences in interpretation by a variety of actors. To illustrate this, it is helpful to consider the following definition given in the influential 2013 Montpellier Panel Report:

At its heart sustainable intensification is about producing more outputs with more efficient use of all inputs – on a durable basis – while reducing environmental damage and building resilience, natural capital and the flow of environmental services. It is also about conserving natural landscapes not only because of the ecosystem services they provide, but also their present and future cultural value.[67]

This definition seems clear and comprehensive. It is only when we examine the terminology in more detail that the complexity of the concept emerges. Does agricultural output only include food or also other aspects, such as biomass for fodder and ecosystem services? What is the scale at which sustainability and environmental damage are assessed? Should sustainability only include environmental dimensions, or also social and economic aspects? Is there agreement on what cultural values have to be preserved, today and in the future? And what do the terms 'intensification', 'productivity', 'sustainability' and 'resilience' really mean?

Intensification and productivity

By 'intensification' we refer to increases in productivity, "the efficiency at which inputs are converted into outputs. Productivity can increase through an increase in outputs, decrease in inputs, or both".[68] Higher efficiency is achieved when more units of output are produced per units of all inputs and through new combinations of inputs and technologies. In most cases, the aim of intensification has been to "raise production, yields and/or income per unit of land, through greater investment of capital or labour and higher use of inputs such as fertiliser or pesticides…"[69] Examples of agricultural intensification include: increasing yields per hectare; increased production from the same amount of water or other inputs, increasing cropping intensity - the number of crops grown per year or season - per unit of land; and changing land-use from low-value crops to those that receive higher market prices.[70]

Although intensification refers primarily to improvements in resource efficiency, some have interpreted it to mean increasing the overall volume of production, which in turn is linked to the perceived need to increase food production by a certain amount in order to feed a growing and increasingly urbanised global population (Box 3).[71] As a result, intensification is increasingly "operationalised" into food security strategies in terms of seeking to produce more, rather than more efficiently.[72] This interpretation is especially erroneous in the context of sustainable intensification, where farmers need to aim not simply at improving relative efficiencies in agricultural production, but also to do so with minimum environmental impacts.[73] Garnett and Godfray seek to clarify this and effectively decouple debates about sustainable intensification from targets for global food production, as we shall see below.[74]

Another question that emerges is what to intensify – i.e. what inputs, what technologies? This depends critically on the outputs whose productivity we want to increase. Conventionally, agricultural productivity has been identified with crop yields and livestock productivity. If intensification is only equivalent to maximising yields, then it follows that higher efficiency should be sought primarily in the use of physical inputs (such as nutrients, seeds and breeds) and in new farming technologies and equipment.

However, this idea of productivity being equivalent to crop yields has been heavily critiqued. The consequent emphasis on 'high-yielding varieties' may be misleading. Such varieties are only more 'productive' in response to certain inputs such as fertilisers and water; while the measurement of output, especially in rural societies, needs to consider much more than just the marketable elements of crops.[75] This critique recognises that agriculture is a multi-functional, multi-output activity producing not only commodities (food, feed, fibre, agrofuels, medicinal products and ornamentals), but also non-commodity outputs such as environmental services, landscape amenities and cultural heritage.[76] If the value of these many outputs is accounted for, then increases in overall productivity may be better achieved through an intensified use of "soft" inputs such as farmers' knowledge and social capital, rather than just physical inputs.

Measures of production based solely on yields not only ignore broader objectives – they also fail to account for the damage that many farming systems have on the environment and human health; these 'externalities' are not included when calculating agriculture's contribution to GDP. In relation to the food security challenge, an excessive focus on yields (and supply) is limiting because it often implies scarce attention to equally important issues of access to food and governance of food systems.

The debate around what sustainable intensification means in practice has led some to propose alternative measures of productivity. Bittman,[77] for instance, has suggested that the productivity of agriculture in relation to food security could be better measured as the number of people fed per acre rather than as tons per acre. One might add that it could also refer to the number of people fed per unit of inputs other than land, such as water, fertiliser, energy, etc. According to this method, the large areas monocropped with maize and other cereals in the USA would rank behind some of the more diversified agricultural systems in China and India, because so much of American cereal production goes to feed animals and fuel cars.[78] Along similar lines, Bourgeois[79] suggests a formula in which the two terms are reversed – as intensifying sustainability. In this re-formulation, sustainability, understood as a combination of the three tenets of sustainable development (economic development, social justice and environmental integrity), replaces productivity as the object of the intensification process. In other words, he proposes intensified sustainability as a way to address the food security challenge rather than sustainable intensification:

Intensified sustainability brings the idea of multi-functionality […] [because] instead of seeing agriculture as the sector which provides food, and the farmers the economic agents who produce the commodities needed for food production, it helps considering many more functions of agriculture and also many other rationalities for the farmers than maximizing or optimizing yields.[80]

Having sustainability as the goal, rather than sustainable intensification, encourages us to challenge conventional systems and pursue more radical and profound changes. For instance, reducing the amount of cereals used as animal feed by the livestock industry and minimising the waste occurring at each stage of the food value chain are just two measures that would allow more people to access food without any need to further increase yields.[81] However, like 'intensification' and 'productivity', 'sustainability' is a term that can be interpreted in many different ways.

Sustainability and resilience

Defining 'sustainability' in relation to agriculture is even trickier than 'intensification' or 'productivity' as it is linked to the values of the person using the term. As sustainable intensification focuses on agricultural production, references in the literature to sustainability tend to refer primarily to environmental aspects, and in some cases to economic ones. However, sustainability is broader than this, as defined by the three pillars of sustainability (economic development, social justice and environmental integrity) in the Bruntland Report.[82] We will return to this point, but first let us deal with the term's environmental aspects.

A useful definition of the environmental dimensions of sustainability is provided by the Royal Society, according to which, "the concept of sustainability in the context of agricultural and food production incorporates four key principles:

1. Persistence: the capacity to continue to deliver desired outputs over long periods of time (human generations), thus conferring predictability;
2. Resilience: the capacity to absorb, utilise or even benefit from perturbations (shocks and stresses), and so persist without qualitative changes in structure;
3. Autarchy: the capacity to deliver desired outputs from inputs and resources (factors of production) acquired from within key system boundaries;
4. Benevolence: the capacity to produce desired outputs (food, fibre, fuel, oil) while sustaining the functioning of ecosystem services and not causing depletion of natural capital (e.g. minerals, biodiversity, soil, clean water)."[83]

Especially important is the concept of resilience and its relationship with diversity and productivity. A system that under normal conditions can guarantee the continuity of production (persistence) is not sustainable if it is not able to withstand perturbation – be it environmental (unpredictable weather), biological (pests and diseases) or social (economic recessions, civil unrest). There are of course trade-offs: farming systems that rely on expensive inputs or technologies may be resilient to environmental stresses in the short term, but less able to withstand climatic shocks and changes in the longer term, and may be less resilient to economic shocks. More diversified systems are usually more resilient (and thus more sustainable) because they provide more options to overcome these shocks.[84] A resilient system, in fact, should not be static, but open and flexible to changing conditions. In order to be adaptable a system should incorporate continuous genetic, biological and social and institutional developments.[85]

Pretty has laid down a useful framework to identify principles that have the potential to increase sustainability and resilience. These include practices that:

1. "integrate biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes,
2. minimize the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers,

3. make productive use of the knowledge and skills of farmers, thus improving their self-reliance and substituting human capital for costly external inputs, and
4. make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management."[86]

This framework is preferable to those discussed earlier in that it includes the human and social capital dimensions so often neglected in the sustainable intensification literature. However, it still does not address trade-offs among different components of sustainability (environmental, social and economic). Definitions of agricultural sustainability should go even further to include economic viability, livelihoods and social equity, as the FAO defines it:

Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable. Agricultural sustainability, therefore, is much more than ensuring protection of the natural resource base. To be sustainable, agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health, and social and economic equity. Sustainable agriculture would contribute to all four pillars of food security – availability, access, utilization and stability – in a manner that is environmentally, economically and socially responsible over time.[87]

Science, technology and local knowledge

Simultaneously improving the productivity and sustainability of a farming system requires both access to technologies and information, as well as to the knowledge that generates new inputs and techniques or novel ways of employing them.[88] These can be provided by scientists employed in conventional research programmes and by private sector entrepreneurs, but can also stem from local and traditional knowledge or from a combination of the two, through interaction between farmers and researchers. In fact, many agroecological practices are derived from traditional knowledge.[89] While science focuses on short-term productivity (i.e. intensification), local and traditional knowledge often prioritises risk reduction (i.e. productivity over time) and sustainability. Local people often have in-depth knowledge of the local environment and an understanding of farming systems as whole, which provides an important complement to science.

Nonetheless, proponents of sustainable intensification have diverse views and priorities when it comes to the role of knowledge and technology. For instance, the Royal Society's report *Reaping the Benefits* focuses on conventional science and in particular on biological sciences; it states that no technology should be ruled out.[90] The FAO report *Save and Grow*, on the other hand, concentrates on smallholder farmers and emphasises knowledge-intensive agriculture, local practices and institutions.[91]

To date agronomic science has focused on understanding and improving crop and animal genotypes and less on improving the conditions for agroecological management. The European Commission Standing Committee on Agricultural Research suggests that priority in publicly funded research should be given to "approaches that focus on low-input high-output systems, integrate historical knowledge and agroecological principles that use nature's capacity".[92] Farmers' agency and knowledge are central to this process; equally important is the availability of advice and information provided through extension services.[93]

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) is unique in the history of agricultural science assessments in that it assesses both formal science and technology and local and traditional knowledge, and addresses not only production and productivity but also the multi-functionality of agriculture. This huge global consultative process was initiated in 2002 by the World Bank and FAO, and its many reports draw on the work of hundreds of experts from all regions of the world. It sees the main challenge of agricultural knowledge, science and technology to be to increase the productivity of agriculture in a sustainable manner so as to address the needs of small-scale farms in diverse ecosystems and create realistic opportunities for their development in the face of low productivity and climate change. It calls for increased public and private investment in agricultural knowledge, science and technology; the development of supporting policies and institutions; the revalorisation of traditional and local knowledge; and an interdisciplinary, holistic and systems-based approach to knowledge production and sharing.[94] However, while widely cited, the IAASTD does not appear to have had much of an impact on mainstream agricultural policies and investments.[95]

Re-rooting sustainable intensification in the food system

Sustainable intensification has a key and proven role to play in making agriculture more sustainable, productive and resilient. But it is important to ensure that its use is held to rigorous criteria, and not allowed to become a vehicle for promoting high external input agriculture or policies which have negative impacts upon local livelihoods. While sustainable intensification can make agriculture more sustainable and productive – the many other factors contributing to food security can only be addressed by placing sustainable intensification within the overarching framework of a sustainable food system.

3

Sustainable intensification is being used in a variety of ways by different actors, partially due to differing conceptions of underlying terminology as discussed in the last section, and partially because of the different values and priorities of the actors involved. The controversy and criticisms surrounding sustainable intensification makes it worth asking whether it is a useful concept to address food security issues, and if so, under what conditions?

It is important to recognise that sustainable intensification has been endorsed by many powerful institutions with influence over the global food system. As such it is essential to be able to engage with the concept, while recognising that its usage by many actors today is problematic and at odds in significant ways with the way it was originally conceived. The term is in widespread use, and is here to stay. Therefore it is important to try to ensure that it is held to rigorous criteria, and not allowed to become a vehicle for promoting high external input agricultural models or policies which have negative impacts upon local livelihoods (e.g. commercial agriculture for export on land that pastoralists depend on for survival).

The task of this section is therefore to clarify what sustainable intensification is, and isn't, and what it can, and can't achieve.

3.1 Intensifying sustainability

Unsustainable food production is arguably the biggest threat to the health of the planet. Reversing it will require curbing agricultural sprawl, rebuilding soils, restoring degraded lands, reducing agricultural pollution, increasing water use efficiency, decreasing the use of external inputs, and greening entire commodity chains.

Agricultural production in the coming decades will take place under increasingly adverse conditions due to land degradation, pollution, water scarcity, climate variability, as well as volatile commodity prices. Because agriculture is the single largest cause of biodiversity loss[96] and one of the major contributors (directly and indirectly) to GHG emissions[97], the challenge of producing more food will likely be a challenge of sustainability, rather than only intensiveness. The need to focus more on sustainability has been recently stressed in reports by UNCTAD, UNEP and IFAD that highlight how current food systems are at risk from gradual degradation of their own ecosystem integrity and services.[98]

A growing body of work is examining what sustainable intensification looks like in practice. Their findings confirm that productivity can be enhanced using low external input techniques that are environmentally, socially and economically sustainable. For instance, one study examined 286 projects in 57 countries in which farmers increased crop yields by an average of 79%, while at the same time raising water use efficiency, improving carbon sequestration and reducing pesticide applications.[99] The Foresight Project looked in greater detail at 40 projects in 20 African countries where practices that might be considered to be sustainable intensification have been applied, and found clear economic benefits for 10.39 million farmers and their families, as well as environmental improvements on some 12.75 million ha of land.[100] The Montpellier Panel reports discuss a number of agroecological and genetic approaches for sustainable intensification in Africa – such as small-scale water harvesting, intercropping, home gardens, integrated pest management, conservation farming and forms of crop and livestock breeding – which have been demonstrated to raise yields and farmers' incomes while bringing myriad environmental benefits. It also discusses other aspects of the rural economy which are important to improving livelihoods such as nutrition, markets and social capital.[101] More in-depth examples of approaches which can contribute to sustainable intensification are given in Boxes 4 and 5.

The research confirms that sustainable intensification can address one key aspect of our current food predicament – namely how to make agriculture more sustainable and productive. Sustainable intensification as originally conceived therefore remains a useful concept, as long as it is remembered that sustainability is at least as important as intensification – if not more so.

It is also important to reiterate that sustainability cannot be considered in terms of its ecological dimensions alone. Rather "the usually de-coupled economic, environmental and social dimensions of sustainability must be brought together in the research and innovation agendas".[102] The conception of sustainability needs to also include social, economic as well as environmental dimensions (e.g., social justice, economic viability and environmental soundness), unlike much of the sustainable intensification literature where sustainability is defined quite narrowly. Supporting sustainable intensification also means nurturing the knowledge and skills which the approach depends upon, as discussed next.

BOX 4: THE SYSTEM OF RICE INTENSIFICATION: A SIGNIFICANT BREAKTHROUGH FOR SUSTAINABLE FARMING

Traditionally, three-week-old rice seedlings are planted in clumps of three or four in waterlogged fields. Using the system of rice intensification (SRI), farmers transplant individual seedlings at 8–15 days old in a widely spaced grid pattern to minimise root competition. They keep the soil much drier and weed frequently – preferably using a surface rotary hoe – to aerate the soil and control weeds. Organic fertilisers are preferred wherever possible because they provide organic matter to the soil, which in turn provides food for soil biota. SRI uses very low density planting in order to enable single plants to develop an extensive root system, thereby making them far more efficient at taking up nutrients from the soil. While it has frequently been characterized as a technology, SRI should instead be viewed "as a *set of practices* to be followed and implemented flexibly and in response to the diverse local agroecological and socio-economic conditions faced by farmers".[103]

SRI was originally developed by a priest in Madagascar on the basis of field practices designed in response to biophysical constraints that existed in the Madagascar Plateau and to the socio-economic needs of rice farmers in the area. In particular, farmers faced shortages of rice seeds and irrigation water, and lacked the resources to purchase inorganic fertiliser and pesticides. The application of SRI led to significantly higher rice yields, as well as savings on seed, water and other inputs.[104] However, SRI requires more and better skilled labour (in particular for transplanting and weeding), making it less well adapted to situations where rice competes for labour with other on- or off-farm activities.[105]

While originally developed for rice, SRI has been applied to other crops such as wheat, potatoes, sugar cane, teff, yams, tomatoes, garlic, aubergine, etc. Its benefits have been demonstrated in over 50 countries. These include: yield increases of 20%-100% or more, up to a 90% reduction in required seed, and up to 50% in water savings.[106]

While SRI has met with a sceptical reception among the international rice research establishment[107], it is viewed by some observers as one of the most significant developments of the past 50 years for the world's 500 million smallholder farmers. In India, farmers have broken yield records for rice and other crops with SRI while using fewer inputs, and state governments such as Bihar are investing heavily in its promotion[108].

Localising knowledge, training and incentives

One key for intensifying sustainability is to provide farmers with the knowledge, training and incentives that they need to put sustainable intensification into practice; and with the enabling conditions to support their existing sustainable practices, the further development of these practices through continuing adaptation and innovation, and the scaling out of such practices to other farmers. Supporters of ecological intensification and low external input agriculture argue that the yield gap (between farmers' actual yields and those obtained in research stations under optimal conditions and input use) could be dramatically reduced if existing agroecological methods and improved varieties originating from both conventional plant breeding and participatory plant breeding (by or with farmers; see Box 5) were more widely available to farmers and were supported by appropriate adaptive research and advisory services. However, after nearly two decades of liberalisation, public sector funding for agricultural research is increasingly focused on the high-tech end of the technology spectrum, while public sector funding to agricultural advisory services remains low. This means the majority of farmers in the developing world do not have access to services to support their needs, including appropriate technologies. Most publicly funded agricultural research institutes in developing countries focus on disseminating a technology package of modern seeds plus chemical inputs, which rarely benefit the most marginalised sectors of society – notably indigenous and traditional women farmers, who are the custodians of diverse local seed systems and traditional agroecological knowledge – and can also lead to indebtedness, soil degradation and a shift away from traditional diets.

Today, the all-important knowledge dimension required for sustainable intensification is at risk of being marginalised, with experiential learning, local innovation and advice on knowledge-intensive sustainable practices now coming mostly from NGO or donor-funded projects and programmes (e.g. farmer field schools on Integrated Pest Management). Ideally, sustainable intensification requires effective partnerships among all the innovation system actors – public, private, NGOs and farmers. Giving farmers more influence and power in these partnerships is likely to favour locally adapted, affordable and therefore sustainable solutions.

BOX 5. PARTICIPATORY PLANT BREEDING BUILDS LOCAL RESILIENCE AND KNOWLEDGE

Participatory plant breeding (PPB), currently in use in many countries around the world, is a collaborative research process for crop improvement. PPB allows farmers and breeders to participate equally in decision making at every stage, from the identification of desirable traits and parent lines, to the evaluation of resulting varieties. PPB enables the use of local varieties which are often more resilient, and modern high yielding varieties, to develop new varieties which are both higher yielding and more resilient. It tailors crop breeding to diverse local environments, greatly improves technology adoption rates, and generates incentives for agrobiodiversity conservation through its use. In Guangxi province in SW China, a maize PPB programme initiated in 2000 has increased yields by 15–30%. This, along with supply to organic restaurants in provincial towns, has enhanced incomes by 30% compared to non-PPB villages growing hybrid maize, and created incentives for the adoption of agroecological farming practices in the PPB villages (such as using ducks to control pests, inter-cropping and use of manure instead of chemical fertilisers).[109] In risk-prone areas in particular, using a diversity of crop varieties may be a better way to sustain yields over time than monocropping because it reduces the risk of crop failure, and using local varieties that are more resilient and adapted to local conditions may be more effective in increasing and sustaining yields than modern high yielding varieties that are less resilient to local conditions.

3.2 Beyond sustainable intensification

Even with a greater emphasis on sustainability, however, sustainable intensification cannot address a host of other issues plaguing the food system, such as highly unequal access and entitlements to food, insecure land tenure, rising demand for resource intensive meat and dairy products, losses and waste of food, inequitable trade rules and market chains, and concentrations of power in the hands of a small number of multinational agribusiness companies. Thus while sustainable intensification does have something important to add to current debates and policies, it is not an overarching framework for addressing food security or the problems of our current food system, nor is it meant to be. For this reason, the concept needs to be situated within a larger food systems perspective, as illustrated in Figure 1. Seen in this light, sustainable intensification is not treated as an all-encompassing paradigm designed to address all aspects of the food system – since its focus is squarely on production – but rather as one component of a larger whole. Simultaneous efforts are needed on multiple fronts to promote food security by bolstering property rights for farmers and ensuring access to food for vulnerable groups, limiting food waste, stemming population growth, curbing demand (particularly for meat and dairy products), preserving agricultural land, and meeting the energy needs of smallholders while limiting fossil fuel intensity. These points are discussed in more depth below.

Enhancing food security through greater equity, access and control

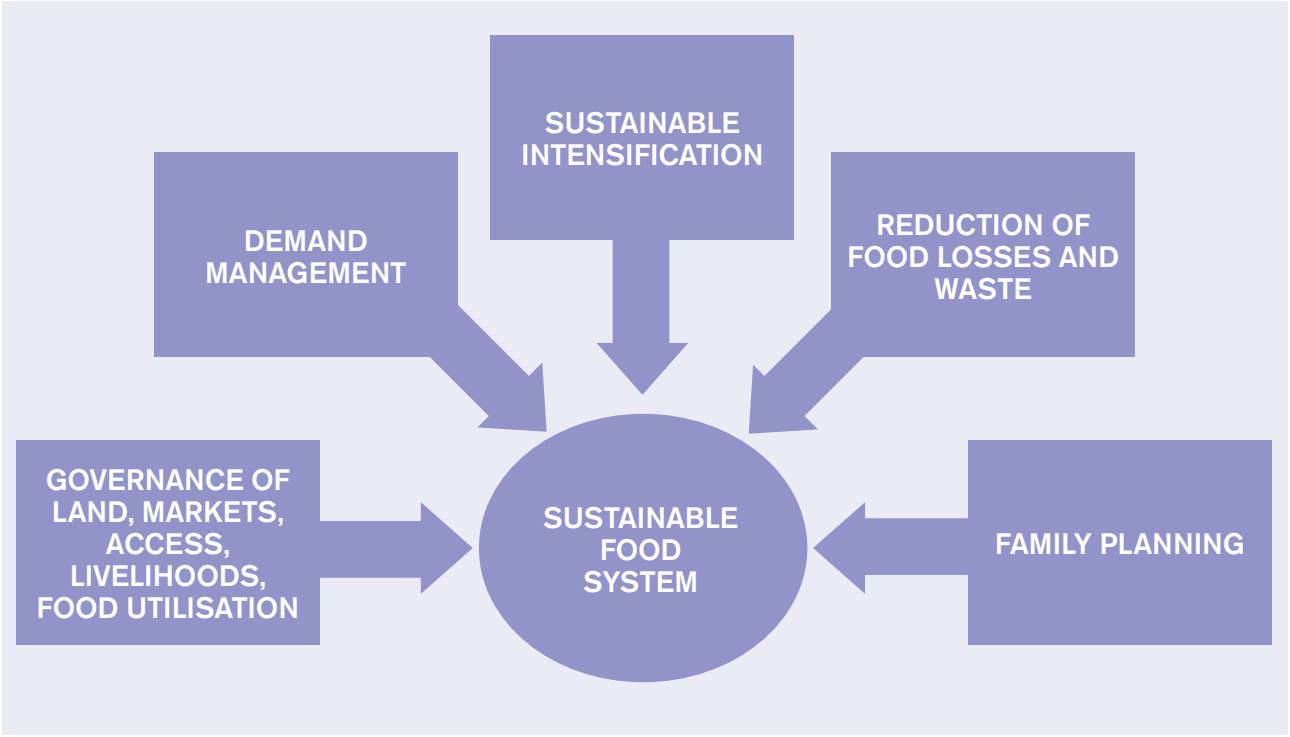
The assumption, explored earlier, that to feed one billion hungry people, global food production must significantly increase over the coming decades, ignores the evidence that hunger is more an issue of access and entitlement to food rather than its total availability. Despite plentiful supplies of food globally, more than 800 million people remain hungry and one-third of the global population suffers from micronutrient deficiencies. Thus, producing more food is no guarantee of worldwide food security, particularly for people suffering from deprivation.

The UN Food and Agriculture Organization (FAO) lists four essential dimensions of food security:[110]

1. **Availability:** The availability of adequate quantities of food of appropriate quality.
2. **Access:** Access by individuals to adequate resources (entitlements) for acquiring foods necessary for a nutritious diet.
3. **Utilisation:** Utilisation of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met.
4. **Stability:** A population, household or individual must have access to adequate food at all times.

Ensuring that the four dimensions of food security are met implies the need for greater emphasis on equity, fairness and local control in agriculture and food systems. Partly for this reason, the food sovereignty

Figure 1: The place of sustainable intensification within a sustainable food system[111]



movement[112] emphasises the need to address issues of power and equity, to ensure farmers' control over land and resource rights, as well as farmers' rights to determine their own food and agricultural regime. At a minimum, food and agricultural systems must enhance the livelihoods and social well-being of those who depend upon them for their livelihoods. In fact, the FAO considers this to be one of five key criteria for sustainable agriculture.[113]

At the same time, food security cannot be considered solely from the perspective of agricultural production systems. In fact, the prevalent production-based approaches to food security overlook many factors that determine access to food for low-income groups. Today over half of the world's people live in urban areas, and large numbers of rural residents buy more food than they sell. "For effective policymaking, the production-based debate on food security must adapt to consider how consumption and urbanisation are transforming rural spaces and economies, food systems and food security. It must focus on access, affordability, safety and nutrition for both rural and urban low-income groups."[114] Narratives which take consumption rather than production as the key entry point for understanding food systems have the advantage of being more inclusive – since consumption is universal – and also better able to reflect the complexity of food issues today for both rural and urban dwellers.[115]

Curbing waste and increasing availability

Food losses and waste are major problems worldwide. At the same time, nearly two billion people are overweight and over 600 million are obese.[116] If consumption and waste are not addressed, further intensification will be needed, leading to worsening degradation of the natural resource base that sustains food production.

Recently there has been more attention given to addressing the problem of food waste. While the scale of the problem is widely regarded to be significant, there is a dearth of reliable, up-to-date figures for the extent of food waste globally. For instance, much of the data on post-harvest losses for developing countries were compiled over 30 years ago.[117] Based on the best available data, the FAO estimates that approximately one-third of all food produced is lost or wasted, amounting to some 1.3 billion tons annually.[118] Reducing these losses by half would save enough food to feed one billion people.[119] On a per capita basis, far more food is wasted in the developed world than in developing countries. In developed countries, much of this food waste occurs at the sales and consumption stage. Several factors contribute to this, such as supermarkets' rejection of food items that fail to meet purely cosmetic criteria for size and appearance, overly conservative use-by dates, as well as losses by consumers due to over-buying. In developing countries,

investments in infrastructure for transportation, storage, cooling and markets are needed to combat harvest and post-harvest losses.[120] Better market systems and market access are also essential.

Meanwhile, obesity is another form of food waste which in 2012 cost the global economy an estimated US$2 trillion, more than alcoholism (US$1.4 trillion), illiteracy (US$1.3 trillion) and climate change (US$1 trillion).[121] Curbing over-consumption through educational and other means would have enormous public health benefits while making more food available on a global basis.

Another way of increasing the availability of food would be to discourage the use of highly productive croplands to grow animal feed. The use of such land to produce corn, soybeans and other crops for animal feed which could be used to grow food for direct human consumption is a colossally inefficient use of resources. In addition to favouring meat production on pasture and grazing lands, one way to at least partially address this conundrum is to return to the practice of feeding food waste rather than grain to omnivorous animals such as pigs.[122]

Re-energising farming

Energy tends to be neglected in discussions of sustainable intensification and food security more generally. In fact, it is doubtful how much longer the highly energy-intensive model of farming prevalent in developed countries can be maintained, based as it is on massive inputs of fossil fuel energy. For instance, in the US, each kcalorie (kilogram-calorie) of food eaten by the consumer requires the consumption of more than 10 kcalories of energy in the food system. "Put another way, the food system consumes ten times more energy than it provides to society in food energy."[123] Large quantities of inorganic fertilisers derived from fossil fuels are applied to soils throughout the world and are crucial to maintaining yields in high external input farming systems.[124] Pesticides are also manufactured with fossil fuels and their production and use is highly energy intensive. However, fossil fuels are the prime culprits in climate change, and are also subject to price volatility and supply shocks. They need to be left in the ground for all of these reasons.

The energy needs of smallholder farmers and of the enterprises that process, store and distribute their produce is a neglected area, but one that is crucial to address if farmers are to improve their productivity. Many of the world's smallholder farmers face a huge deficit in access to energy services. This issue needs to be addressed throughout the value chain – from farm to retail – in order to promote greater food security.[125] However, replicating the fossil fuel dependence of modern agriculture for production, processing and transport is untenable in light of the issues discussed above. Increasing the dependency of agriculture in developing countries on fossil fuels also has the potential to worsen the vulnerability of smallholders, who are sensitive to changes in input prices. Technologies and equipment which make use of renewable energy (e.g. biogas, watermills for grinding grain, solar powered water pumps and drip irrigation) and locally available materials (e.g. agro-processing industries powered by farm waste) should be favoured.

Greening the economy

A food systems perspective is essential to achieving greater food security, but even that lens is not wide enough. Many factors lying outside of the food and agricultural sector exert a powerful influence on our future ability to feed ourselves. For instance:

- The availability of agricultural land for food production is closely related to the use of land for biofuel production, urbanisation patterns, infrastructure construction, and myriad other forms of land use influenced by investment and trade. Preserving the arable land base, for example, is dependent upon the type of urbanisation a given country is pursuing (e.g. sprawl vs. compact cities) and addressing "land grabs' in developing countries, particularly those for non-agricultural uses such as mining, infrastructure, tourism, etc. Effective policies are needed to discourage the conversion of agricultural land to non-farm uses.
- Population growth is an important source of land fragmentation as well as rising demand for food. Family planning, female education and empowerment are vital in terms of curtailing population growth rates and hence demand for food.
- Decisions on overall energy use are likely to be at least as important for our future ability to feed ourselves as those made directly in agriculture, because if we cannot control catastrophic climate change, no amount of adaptation will be sufficient.[126] Climate change is already affecting global agricultural production, but over 70 percent of greenhouse gas emissions are generated outside of the agricultural sector. Fossil fuels underpin the food system around much of the world, yet these fuels are the prime culprit in climate change and are subject to supply shocks. A rapid transition to renewable energy sources is imperative for all of these reasons.

The challenge of feeding the world in the coming decades depends to a large extent on addressing these larger issues, yet this is rarely acknowledged in discussions of sustainable intensification or food security generally. With so many of the drivers undermining food security lying outside the food system, achieving food security requires nothing less than a food system perspective situated within the larger context of a green economy.[127]

Looking forward

As long as we are clear about what sustainable intensification is and is not, it can serve as a useful guiding framework for addressing *one critical aspect* of the global food system in the 21st century, namely food production. The next step will be to develop clear criteria for carrying the sustainable intensification concept forward in different countries through multi-stakeholder dialogue involving representatives of food insecure/vulnerable groups and building upon local knowledge and priorities. These criteria should give at least equal weighting to sustainability issues (including livelihoods, social justice, economic viability and environmental soundness) as to intensification. They should also reflect the fact that sustainable intensification can only address one facet of the global food system, namely production; other approaches will be needed to tackle consumption and waste, access and entitlements, markets and power.

How to achieve sustainable intensification will partly depend on the starting point – e.g. if systems are already sustainable, they may need to focus on becoming more productive, and vice versa. While the most appropriate measures will tend to vary by locality, there are some general principles that policies and initiatives designed to sustainably intensify agricultural production would do well to consider:

- Provide incentives to drastically reduce the environmental impacts of crop and livestock production
- Promote low-cost approaches which farmers can control
- Enable and invest in local innovation and adaptation using both local/traditional knowledge and science
- Recognise the important role of public sector funding for agricultural research, given that sustainable intensification will entail reduced use of external inputs in many regions and therefore reduced incentives for private-sector involvement.
- Discourage the use of highly productive croplands to grow animal feed
- Address the energy needs of smallholders while limiting fossil fuel intensity and reducing GHG emissions
- Strengthen the voice of smallholders and vulnerable groups in decisions about agriculture and land use.
- Focus on enhancing the economic value of farming as well as its productivity.

Food security is a complex and multifaceted issue for which there are no silver bullets. An integrated approach is needed, as action is required on all fronts. Sustainable intensification is a useful guiding framework for addressing one key component of the food system – namely food production. It is not an adequate framework for addressing food security overall. That requires nothing less than a food system perspective situated within the larger context of a green economy.

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Notes

1 According to the Center for Agroecology and Sustainable Food Systems, University of California, Santa Cruz. www.casfs.ucsc.edu.

2 'Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (FAO, 1996).

3 The Royal Society, 2009, p.ix.

4 The Royal Society, 2009.

5 Godfray *et al*., 2010.

6 Pretty, 1997.

7 For instance, see Chapter 5 of the IFAD Rural Poverty Report 2011 (IFAD, 2010).

8 FAO, 2011.

9 Pretty, 1997.

10 Reardon et al., 1995.

11 Ibid.

12 Ibid, p.1.

13 Pretty, et al., 1996, pp. 4–5.

14 Foresight, 2011.

15 Feed the Future factsheet, available at http://feedthefuture.gov/sites/default/files/resource/files/ftf_factsheet_fsicsustainableint_nov2013.pdf.

16 http://www.nepad.org/system/files/Keynote%20Speech%20NH.E.%20Dr%20Ibrahim%20Mayaki.doc

17 FAO, 2011.

18 IFAD, 2010.

19 Rijsberman, 2014; CGIAR, 2014.

20 Jawahery, undated.

21 Agricultural Biotechnology Council webpage, see www.abcinformation.org/index.php/knowledge-hub/features/biotech-for-sustainability

22 UK Department for International Development, 'DFID–Bill and Melinda Gates Foundation (BMGF) Strategic Collaboration Portfolio for Sustainable Intensification of Agriculture', see www.dfid.gov.uk/r4d/Project/60792/Default.aspx.

23 Population Institute, undated.

24 Scoones, 2014.

25 The Royal Society, 2009, p. 10

26 Garnett and Godfray, 2012a.

27 Ibid, p.21

28 Ibid, p.18

29 Agricultural Biotechnology Council webpage, ibid.

30 The One Acre Fund argues similarly - see https://sustainabledevelopment.un.org/getWSDoc.php?id=751

31 Jawahery, undated.

32 Garnett and Godfray, 2012a, p. 8

33 Pretty, 1995.

34 Porritt, 2012.

35 Collins and Chandrasekaran, 2012, p. 23.

36 Hird, 2012.

37 Scoones, 2014.

38 Ibid.

39 Collins and Chandrasekaran, 2012; Parmentier, 2014.

40 Hird, 2012, p. 20.

41 Hird, 2012, p. 21.

42 Holt-Giménez and Altieri, 2013.

43 Levidow *et al*. (2014) make a similar argument in examining whether agroecological research is confirming or transforming the dominant agro-food regime.

44 Altieri, 1995.

45 Wezel et al., 2009.

46 Silici, 2014.

47 E.g., Montpellier Panel, 2013; Pretty et al., 1996; Pretty and Bharucha, 2014.

48 Wibbelmann, 2013.

49 UNCTAD, 2013; UNEP, 2012; CGIAR-WLE 2013; de Schutter, 2010; McIntyre, 2009.

50 Dore et al., 2011, p. 197.

51 The Montpellier Panel, 2013.

52 Tittonell, 2014.

53 Ibid, p.55.

54 Arguably the issue is not simply about the need to produce more food, but also other materials such as fuel, firewood, feed and fibre. However, in the interests of limiting the scope of what is already a very large topic, we are confining our discussion to food. See Pretty and Bharucha, 2014 for a broader treatment of the concept and the need to embed it within green economies.

55 Garnett and Godfray, 2012a.
56 Bruinsma, 2011.
57 Alexandratos and Bruinsma, 2012.
58 Ibid.
59 Tilman, *et al*., 2011.
60 Foley *et al*., 2011, p. 337.
61 World Food Programme webpage, www.wfp.org/hunger/causes.
62 Ibid.
63 FAO, 2011.
64 World Food Programme statistics, www.wfp.org/hunger/stats.
65 Foley *et al* (2011) do discuss the potential for increased food delivery by shifting diets and reducing food waste. See pp. 340–341.
66 Tomlinson, 2011.
67 The Montpellier Panel, 2013, p. 11.
68 DEFRA, 2012, p. 6.
69 The Montpellier Panel, 2013, p. 8.
70 Foresight Project on Global Food and Farming Futures, 2010, p. 6
71 Garnett and Godfray, 2012a.
72 Bourgeois, 2013, p. 7.
73 Fish et al, 2013.
74 Garnett and Godfray, 2012a.
75 Shiva, 1989.
76 McIntyre *et al*., 2009, p. 4.
77 Bittman, 2013.
78 Ibid.
79 Bourgeois, 2013.
80 Ibid, p. 8.
81 Tudge, 2012, p. 15; Owen, 2012, p.17
82 World Commission on Environment and Development, 1987.
83 The Royal Society, 2009, p. 7.
84 Garnett and Godfray, 2012a, p. 47.
85 Tudge, 2011.
86 Pretty, 2008, p. 452.
87 FAO, 2013, p.11.
88 The Montpellier Panel, 2013, p. 10.
89 Silici, 2014.
90 The Royal Society, 2009, p.8.
91 FAO, 2011.
92 European Commission, 2011.
93 Tudge, 2011.
94 Heinemann *et al*., 2009.
95 See http://www.ard-europe.org/fileadmin/SITE_MASTER/content/eiard/Documents/Policy_Briefs/EIARD_1.2_IAASTD_policy_brief.pdf
96 European Commission, 2011.
97 McIntyre *et al*., 2009; Russell, 2014.
98 UNCTAD, 2013; UNEP, 2012; IFAD, 2011.
99 Pretty *et al*., 2006.
100 Pretty *et al*., 2011.
101 The Montpellier Panel, 2013; Juma *et al*., 2013.
102 Bourgeois, 2013, p. 6.
103 Stoop, 2011, p.445.
104 Ibid.
105 https://sriwestafrica.files.wordpress.com/2014/05/sri-technical-manual-version-21.pdf
106 For details see the SRI International Network and Resources Center webpage at http://sri.ciifad.cornell.edu.
107 E.g., Dobermann, 2003; Sheehy *et al*., 2004.
108 Vidal, 2013.
109 Song and Li, 2011; Swiderska et al., 2*011.*
110 FAO, 2006.
111 Garnett & Godfray, 2012a, p.15
112 See www.foodsovereignty.org; www.viacampesina.org
113 FAO, 2013a.
114 Tacoli and Vorley, 2015.
115 Ibid.
116 See World Health Organization obesity factsheet: www.who.int/mediacentre/factsheets/fs311/en/
117 Parfitt *et al*., 2010.
118 Gustavsson *et al*., 2011.
119 Bergenfield, 2014.
120 Ibid.
121 Smith, 2014; Dobbs *et al*., 2014.
122 See www.thepigidea.org
123 Giampietro and Pimentel, 1993.
124 Inorganic fertilisers are applied in excessive quantities in many parts of the world, such as China; these applications could be reduced without adversely effecting crop yields. At the same time, those parts of Africa where little or no inorganic fertiliser is currently being used would arguably benefit from increased applications.
125 Best, 2014.
126 Brown, 2012.
127 For a discussion of the nascent green economy and the place of agriculture within it, see Pretty 2013.

Sustainable intensification is receiving growing attention as a way to address the challenge of feeding an increasingly populous and resource-constrained world. But are we asking too much of it? Nearly 20 years after the concept was developed, this paper revisits the term and proposes what sustainable intensification is – a useful guiding framework for raising agricultural productivity on existing arable land in a sustainable manner; and what it is not – a paradigm for achieving food security overall. The paper summarises the history of and controversy surrounding the term, its main assumptions and risks, as well as its value for the future. We call for a re-rooting of sustainable intensification as one key element of a sustainable food system situated within a green economy.

IIED is a policy and action research organisation working to promote sustainable development – development that improves livelihoods in ways that protect the environments on which these are built. Based in London and working on five continents, we specialise in linking local priorities to global challenges. In Africa, Asia, Latin America, the Middle East and the Pacific, we work with some of the world's most vulnerable people to ensure they have a say in the decision-making arenas that most directly affect them – from village councils to international conventions.

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