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A free and evolving resource to empower informed discussion on sustainable food systems

Building Block

What is sustainable intensification?

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Contents

Why should you read this building block?

New approaches to agriculture are required if we are to reduce the environmental impacts of farming while also feeding more people with a sufficient quantity and diversity of nutritious and safe foods.

This building block explains the concept of sustainable intensification.

Definitions

Sustainable intensification (SI): is a recently developed concept that is understood in different ways by its critics and supporters. A common understanding is that it denotes the principle of increasing or maintaining the productivity of agriculture on existing farmland while at the same time, reducing its environmental impacts. Understood in this way, SI designates a goal for the development of agricultural systems but does not, a priori, favour any particular agronomic route to achieve it. It may involve the intensification of different types of agricultural inputs (e.g. of knowledge, biotechnologies, labour, machinery) and apply these to different forms of agriculture (e.g. livestock or arable; agroecological or conventional). Forms of intensification that can be called sustainable intensification must lower environmental impacts and land use, relative to yields. However, for some, to merit the term 'sustainable' social, economic, and ethical criteria must also be considered.

Agricultural Intensification: is the process of intensifying the input of agricultural resources (e.g. seeds, labour, fertilisers, pesticides, technologies, knowledge) to increase the level of yield per unit of farmland or livestock. Agricultural intensification is not always clearly nor consistently defined and is often confused with the term intensive agriculture. Unlike intensive agriculture, which could be seen as a specific system of agronomy, agricultural intensification is a general process that can apply, in principle, to any type of agricultural production. Examples of agricultural intensification may range from using new pesticides in intensive agriculture to intensifying the use of indigenous and context specific knowledge in local farming practices. Although agricultural intensification can take many forms, it always involves the intensification of some types of agricultural input with a view to increasing yields.

Intensive arable agriculture (IAA): is often used synonymously with the term industrial agriculture and conventional farming. IA is generally used to denote farming systems that use modern technologies and economies of scale to maximise yields relative to land use and production costs (e.g. costs of labour, technology, seeds, fertilisers, and pesticides). IA is associated with homogeneous landscapes and large fields with low crop-diversity, and high use of chemical fertilisers, agrochemicals, and irrigation. This combination of agricultural technologies became common following the Green Revolution in the mid-20th century. While IA aims to increase agricultural efficiency and so as a side-effect reduces environmental impacts per unit of output, due to its often-large scale, it can result in a concentration of environmental impacts at the local scale.

Ecological intensification (EI): is the principle of using the natural functionalities of an ecosystem to produce greater amounts of food, fibre, and fuel in sustainable ways. Underpinning EI is the idea that ecological functions (e.g. pollination and predator/prey relationships) can be integrated into agricultural practices, ideally leading to 'agroecosystems' that are sustained by natural processes and avoid many negative environmental impacts. Ecological intensification is closely related to the concepts of sustainable intensification and climate smart agriculture, but differs in its strong focus on the potential of enhancing ecological processes in food production.

Climate smart agriculture (CSA): often discussed in the context of low-income countries, CSA was first introduced by the FAO in 2010 as an integrated approach geared at reorienting and redesigning agricultural systems to address and build resilience to climate change. CSA involves three interconnected elements: increasing agricultural productivity and incomes; adapting and building resilience to climate change; and the mitigation of greenhouse gas emissions. It aims to identify context specific agricultural strategies supporting these elements and guide coordinated actions among stakeholders (e.g. farmers, researchers, private sector, civil society and policy makers) from the farm to the global level. CSA is criticised for justifying nearly any form of agriculture (thereby 'greenwashing' unsustainable practices) and for failing to address enduring inequalities in food production and distribution. CSA is closely related to the concepts of sustainable intensification and ecological intensification but differs from them in its strong focus on planning and implementation for climate change adaptation and mitigation, and less on reducing environmental impacts beyond emissions.

Agroecology (as a practice): agroecology can be defined as a range of agricultural practices that are based on applying ecological concepts and principles to optimize interactions between plants, animals, humans, and the environment. Agroecology also places strong emphasis on the social and ethical aspects of food production. Its advocates tend to have a preference for organic practices (e.g. the avoidance of mineral fertilisers and chemical inputs, and instead prefer the use of biofertilisers, natural pesticides and crop rotation), it also emphasises the need for a 'multifunctional' farm system to produce both food and non-food outputs, and for smallholder and indigenous, as opposed to large scale farming. Agroecology has been interpreted in different ways: it also refers to a social movement and field of science.

1. Introduction

Food, biofuel and fibre production are major contributors to climate change, resource use, and the destruction of biodiverse ecosystems and the services they provide. It is essential that agriculture's environmental impacts are reduced, but this cannot be achieved in isolation from the need to ensure ***food security*** (see our building block on food security) for a growing global population. Billions of people worldwide suffer from various forms of ***malnutrition*** (see our building block on malnutrition), while the average diet of a growing and urbanising world population is becoming more resource intensive.

Sustainable intensification (SI) has been suggested by some as one contribution to reconciling the need for more environmentally benign agriculture while advancing global food security. It denotes the linked goals of maintaining or increasing the productivity of existing farmland, while reducing the environmental impacts of agriculture. SI will need to be accompanied by other efforts, including those that address inequitable food distribution, unsustainable consumption patterns, and excessive food waste (see Figure 1)[1-2].

SI has evolved alongside closely related concepts, including ***agroecology***, ***climate smart agriculture***, and ***ecological intensification***[3-5]. These concepts try to clarify priorities and guide efforts for the sustainable development of agriculture. Addressing similar topics from slightly different angles, both SI and these other related concepts have been variously debated, endorsed, and rejected by different stakeholders.

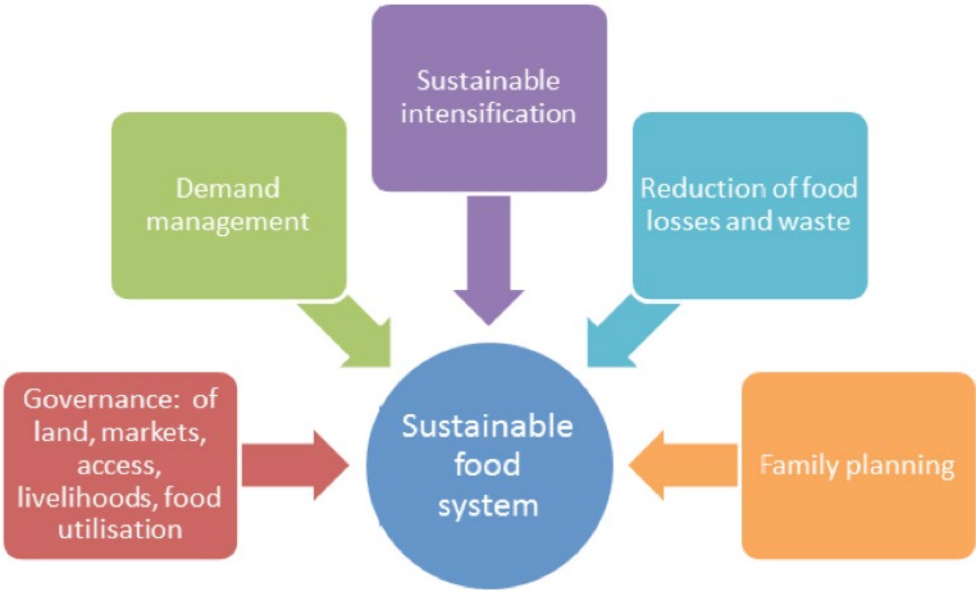

Figure 1: Sustainable Intensification amidst other mechanisms for achieving food system sustainability. Reproduced from Garnett and Godfray, 2012[3].

2. What is Sustainable Intensification?

2.1 A disputed concept

SI is a fairly new and still evolving concept. The concept originated in the context of efforts to increase the productivity of smallholder agriculture in African countries during the 1990s[6]. More recently, SI has been adopted by governments, agribusinesses and international development organisations (including the ***FAO*** and the World Bank) and has been used to denote a general guiding principle for the development of agriculture[7].

SI was defined in 2009 by the UK's Royal Society as an aspirational approach to ***agricultural production*** wherein "yields are increased without adverse environmental impact and without the cultivation of more land"[8]. This commonly used definition describes a goal and guideline for the development of agriculture, but leaves open how (i.e. using which farming methods) SI could be achieved.

Different interpretations of sustainable intensification can be found and the concept has been used in very different, sometimes conflicting ways, from an (alleged) vindication of business-as-usual farming practices, to a call to radically redefine current systems of agricultural production[7,9]. Common criticisms include that sustainable intensification is greenwash, 'oxymoronic' or too vague to be useful[5,7,10]. The looseness of the concept and its perceived association with particular stakeholders or ideologies also means that it has been endorsed by some stakeholders and rejected by others.

2.2 A guiding principle for the sustainable development of agriculture

Underpinning the concept of sustainable intensification as it is commonly used by academics, and reflected in the Royal Society's definition, are three important and widely accepted principles for the sustainable development of agriculture as follows[3]:

2.2.1 A frozen agricultural land footprint

Most of the land potentially available for conversion is currently forest, wetland, or grassland. Converting these lands nearly always results in substantial releases of greenhouse gases, threatens a considerable portion of the world's terrestrial ***biodiversity***, and can disrupt existing ***ecosystem services*** (e.g. flood and drought prevention)[3,11,12].

A core principle of sustainable intensification is to confine food production to existing farmland, which in the context of a growing global population requires continuous improvements in yield in regions of the world where there is currently a ***yield gap*** (see below). In this sense, sustainable intensification is a strategy for ***land sparing*** at global and regional levels (see our building block on the land sparing-sharing continuum).

2.2.2 Reduced environmental impacts

Many farming techniques that were introduced during the Green Revolution and which have now become mainstream, entail high inputs of synthetic chemical fertilisers, pesticides, tillage, and irrigation that have profound environmental impacts, and which can potentially undermine future food production[3].

Runoff from fertilisers, for example, can pollute natural habitats and lead to the ***eutrophication*** of surface waters[12]. In addition, pesticides may harm ecosystems and accumulate in food chains, while high levels of water extraction for irrigation can impact on aquatic ecosystems and limit water availability for other purposes (e.g. domestic use)[12,13].

Sustainable intensification aspires to intensify the productivity of agricultural land, while reducing harmful resource inputs and any resulting environmental impacts of agriculture to an absolute minimum.

2.2.3 Increased yields

More controversial is SI's call to increase yields. While it is often argued that global agricultural yields need to increase in order to meet a growing world population's need for food, critics point out there is currently enough food to feed everyone, and yet people still go hungry. Food insecurity can thus be seen as a failure of socio-economic access to safe and nutritious food, rather than as a simple consequence of insufficient food supply[3].

If and to what extent an increase in global food production will be required also depends on the extent to which issues with distribution, demand and waste as well as population growth are addressed[3]. Rather than reaching predefined global production levels, SI therefore aims to increase the productivity of existing farmland where this is possible: increasing outputs (yields) relative to agricultural inputs (e.g. water, energy, land) and environmental impacts (e.g. greenhouse gas emissions and water pollution)[3]. Its productivity potential also needs to be secured and enhanced through, for example, a focus on building or restoring good quality soils and natural capital.

In addition, ensuring SI's sustainability aspect may mean that in some areas yields or yield gains are sacrificed in exchange for better environmental outcomes[14]. SI may require limiting intensification or even de-intensifying where increasing yields causes unacceptable environmental damages. Some would also argue that in order to become truly 'sustainable' in the broadest sense of the word (i.e. a sense that encompasses social, economic and ethical concerns such as smallholder ***livelihoods*** or animal welfare), intensification may also need to be limited or reversed in some contexts.

3. What does Sustainable Intensification involve?

There is disagreement about what types of agricultural practices constitute SI. For instance, it is common for agri-businesses to frame SI as denoting business-as-usual industrial farming, including incremental improvements in environmental impacts resulting from more efficient modes of production. However, many argue that this will be insufficiently impactful to satisfy the three principles outlined above, which broadly describe the parameters of SI, and to align the concept with the twin goals of achieving food security (across scales) within the necessary environmental and social constraints of a sustainable food system (see Figure 2)[14].

3.1 Sustainable intensification raises complex questions

Both food security and food system sustainability each come with their own complexities. Achieving SI therefore requires that a range of complex topics from debates on food security and food system sustainability are balanced and reconciled as best as possible (see Figure 2)[3,14]:

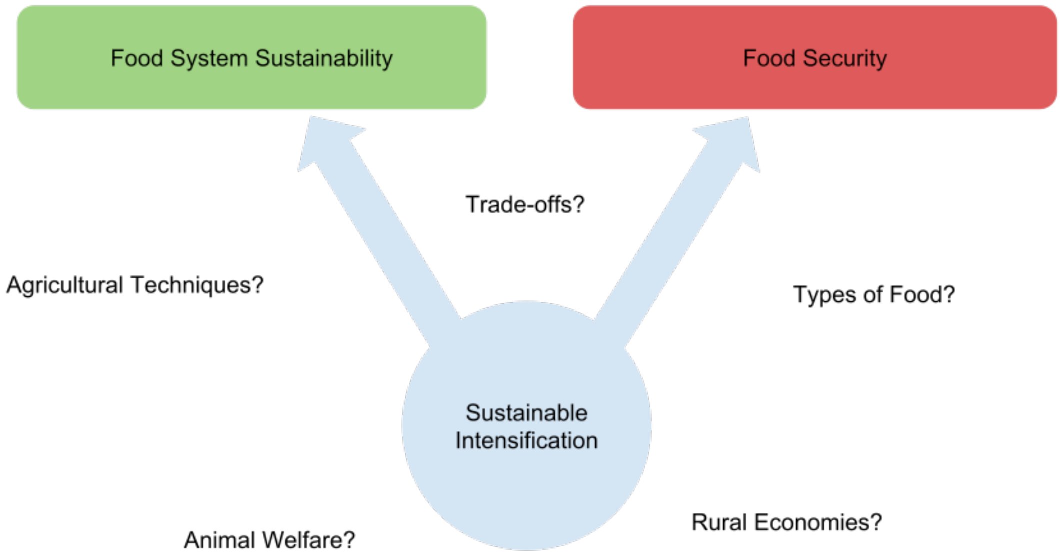

Figure 2: In order to promote food security and food system sustainability, SI needs to deal with a broad range of questions and potential trade-offs[15].

Agricultural techniques. A first question to consider is what types of agricultural techniques SI involves. Sustainable intensification does not a priori include or exclude a range of agricultural techniques[3]. It could, amongst others, incorporate techniques drawn from ***biotechnology*** (e.g. genetic modification), ***precision farming*** (e.g. robotics and big data to improve the timing and spatial allocation of water and nutrients), agroecology (e.g. intercropping) and ***organic farming*** (e.g. closing nutrient loops via the integration of crop and livestock farming)[14]. To reach the aims of increasing yields and lowering environmental impacts, SI will need to incorporate ideas from different agricultural approaches and apply them in ways that fit different local contexts.

Types of food. What types of food need to be produced to foster food security and lower environmental impacts in local contexts? Food security requires not just the supply of any type of food, but rather that people have access to a sufficient, safe and diverse range of nutritious foods that satisfy a healthy diet (see our building block on food security). Different approaches to agriculture may, for example, influence the diversity and affordability of foods available at local markets. At the same time, these foods will need to be produced in ways that minimise environmental impacts: increasing the production of resource intensive foods (e.g. meat and dairy products) or of crops grown via soil-depleting methods may not lead to improved environmental performances and may even undermine future generations' access to sufficient amounts of safe and nutritionally adequate food.

Yields and/or the environment. How should decisions be made when there are trade-offs between yields and environmental impacts? Under what conditions and in which contexts must yields or yield gains be sacrificed for environmental outcomes? SI could, for example, involve intensification in some areas and deintensification in others. It may be desirable to take some habitats critical for biodiversity as well as lands that are not agriculturally productive completely out of agriculture[14]. Equally, significant yield increases may not need to come from further intensifying already intensified agriculture, but could particularly result from the sustainable intensification of farmland that is below its current yield potential[16]. Accordingly, to achieve both its *sustainability* and *intensification* aspects, SI will require different actions depending on local contexts and the current statuses of agricultural systems in different regions of the world.

Livelihoods and rural economies. In many countries, rural economies are responsible for a major part of agricultural production[4]. In some of these contexts, the concern is that some methods of SI may favour large national and international corporations by the techniques and inputs (e.g. seeds, fertilisers, technologies, knowledge) they require. Approaches to sustainable intensification will need to be available to and affordable by smallholder farmers in order to support and enhance their livelihoods and food security[17].

Scale levels. The principle of sustainable intensification can be addressed at different scales, ranging from the farm, to the regional and global level. There can be differences between the types of actions that are required to balance and reconcile the goals of food security and food system sustainability at these different levels. This may, for example, influence how trade-offs will be made between global environmental goals, and regional environmental impacts and food security. To manage these trade-offs, SI needs to be embedded within broader governance frameworks that are geared at optimising food security and food system sustainability across different scales in ethical ways.

Animal health and welfare. Sustainable intensification has its origins in crop production, but has also sparked controversy on animal health and welfare when applied to livestock farming[3]. Some approaches to SI may improve productivity and animal welfare simultaneously (e.g. good veterinary care and more nutritious feeding). In other cases, however, the goal of increasing productivity may be incompatible with improving animal welfare. Which trade-offs between these two goals will still count as being sustainable intensification? The idea of SI will need to consider these conflicting ethical viewpoints: where some will see 'good' animal welfare as a non-negotiable precondition to any increase in productivity, others may value productivity and the benefits this brings to humans over animal welfare.

3.2 Sustainable intensification is open-ended and context dependent

There are currently no clear-cut answers to these major questions and many more relating to SI. However, in the pursuit of SI, and in order to achieve the twin aims of food security and food system sustainability, it will be necessary to continuously engage with them. It is likely that different answers will apply to different contexts and at different scales, resulting in a patchwork of approaches and trade-offs; operating within broader governance frameworks (such as climate and biodiversity conventions and legislation) that set limits and shape decision making on what forms of ***agricultural intensification*** are deemed sustainable, in what context.

Glossary

Agricultural intensification
Agricultural intensification is the process of increasing the inputs of agricultural resources (e.g. seeds, labour, fertilisers, pesticides, technologies, knowledge) to increase the level of yield per unit of farmland or pasture. Agricultural intensification is not always clearly or consistently defined and is often confused with the term intensive agriculture. Unlike intensive agriculture, which could be seen as a specific system of agronomy, agricultural intensification is a general process that can apply, in principle, to any type of agricultural production. Examples of agricultural intensification may range from using new pesticides in intensive agriculture to intensifying the use of indigenous and context-specific knowledge in local farming practices. Although agricultural intensification can take many forms, it always involves the intensification of some types of agricultural input with a view to increase levels of yields.

Agricultural production
Agricultural production is the range of practices and approaches that are employed to transform agricultural inputs (e.g. labour, knowledge, land, water, seeds, fertilisers, pesticides) into agricultural outputs (e.g. yields and environmental impacts). Different types of agricultural production include precision farming, agroecology, organic farming, and intensive livestock farming.

Agroecology
Agroecology can be defined as a range of agricultural practices that are based on applying ecological concepts and principles to optimize interactions between plants, animals, humans, and the environment. Agroecology also places strong emphasis on the social and ethical aspects of food production. Its advocates tend to have a preference for organic practices (e.g. the avoidance of mineral fertilisers and chemical inputs, and instead prefer the use of biofertilisers, natural pesticides and crop rotation), it also emphasises the need for a 'multifunctional' farm system to produce both food and non-food outputs, and for smallholder and indigenous, as opposed to large scale farming. Agroecology has been interpreted in different ways: it also refers to a social movement and field of science.

Biodiversity
Biodiversity refers in the broadest sense to the variety and variability of living organisms in a particular area, or on earth in general. More specifically, the concept is used to denote different aspects of the variety and variability of life, e.g. the number of species in an area (species richness) or the size of species' populations (species abundance). Biodiversity is measured in different ways and at various scales from the genetic through to the landscape level.

Biotechnology
Biotechnology is defined by the United Nations as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". Applied to agriculture, biotechnology involves controversial as well as uncontroversial practices. Examples of biotechnology are the genetic engineering of crops (GMOs), conventional cross-breeding, breeding based on individual plants' and animals' genetic traits (molecular marking), cloning animals, and the production of new vaccines using microbiological methods.

Climate smart agriculture
Often discussed in the context of low-income countries, CSA was first introduced by the FAO in 2010 as an integrated approach geared at reorienting and redesigning agricultural systems to address and build resilience to climate change. CSA involves three interconnected elements: increasing agricultural productivity and incomes; adapting and building resilience to climate change; and the mitigation of greenhouse gas emissions. It aims to identify context specific agricultural strategies supporting these elements and guide coordinated actions among stakeholders (e.g. farmers, researchers, private sector, civil society and policy makers) from the farm to the global level. CSA is criticised for

justifying nearly any form of agriculture (thereby 'greenwashing' unsustainable practices) and for failing to address enduring inequalities in food production and distribution. CSA is closely related to the concepts of sustainable intensification and ecological intensification but differs from them in its strong focus on planning and implementation for climate change adaptation and mitigation, and less on reducing environmental impacts beyond emissions.

Ecological intensification
Ecological intensification is the principle of using the natural functionalities of an ecosystem to produce greater amounts of food, fibre, and fuel in sustainable ways. Underpinning EI is the idea that ecological functions (e.g. pollination and predator/prey relationships) can be integrated into agricultural practices, ideally leading to 'agroecosystems' that are sustained by natural processes and avoid many negative environmental impacts. Ecological intensification is closely related to the concepts of sustainable intensification and climate smart agriculture, but differs in its strong focus on the potential of enhancing ecological processes in food production.

Ecosystem services
The tangible and intangible benefits that are provided by ecosystems to humans, which both enable human life and that contribute to its quality. Ecosystem services include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.

Eutrophication
Eutrophication refers to the buildup of nutrients in a body of water (e.g. nitrogen and phosphorus) to a level in excess of what would occur naturally and to which aquatic ecosystems are adapted. This can result in detrimental impacts on many aquatic plants and animals, as well as the rapid overgrowth of some plants and algae.

Food security
Food security is an idealised state or goal where all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Intensification
Intensification refers to a process by which farming systems (for crops or livestock) are reorganised – often through the application of new technologies, economies of scale, and the use of additional inputs, such as nutrients, chemicals, energy and water – in order to produce more of a desired output (e.g. meat) while using less land, human labour, or capital. The result is that the costs of production for a given amount of food are reduced, thereby increasing profits through larger profits per unit of food, or by expanding total consumption through lower prices, enabling more people to buy more. Often, environmental impacts per unit of product are also reduced, but may be counterbalanced by increases in total production. The impacts of intensification processes on animal welfare, biodiversity, and other issues is also a widely held concern.

Land sparing
Land sparing is the principle of segregating land for nature conservation from land for food (or agricultural) production within a region. It consists of high-yielding farmland with relatively lower biodiversity, with the remaining land being spared for nature conservation. Land sparing sits at one end of the two extremes of the land sparing-sharing continuum. It has in particular been criticised for its (supposed) connection to environmentally unsustainable intensive agriculture and for undermining the food security of smallholder farmers and rural economies.

Livelihood
A livelihood is a person's, household's, or group of people's means of making a living. It encompasses people's capabilities, assets, income, and activities that are required for securing the necessities of

life, such as food, water, medicine, shelter and clothing.

Malnutrition
Deficiencies, excesses or imbalances in the energy, macronutrients or micronutrients that a person obtains, either because their diet is lacking or because their body is not able to fully absorb the nutrients from the foods eaten, e.g. due to illness. Malnutrition is an umbrella term that includes overnutrition (an excess of food energy), undernutrition (a lack of food energy and macronutrients such as protein), and micronutrient deficiencies (insufficient micronutrients such as iron, vitamin A or iodine).

Organic farming
Organic farming is an approach to farming in which synthetic chemical insecticides and herbicides and inorganic fertilisers are entirely or largely avoided. Underpinning organic farming is the idea that farming should rely on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects (e.g. agrochemicals such as pesticides and synthetic fertilisers). Certification bodies (e.g. the Soil Association in the United Kingdom) specify the practices, methods of pest control, soil amendments and so forth that are permissible if products are to achieve organic certification.

Precision farming
Precision farming is an agricultural management practice that aims to supply plants or animals with precisely the amounts of agricultural inputs (e.g. water, pesticides, and fertilisers) they need at a specific location and moment in time, thereby increasing efficiency by reducing the total inputs needed for agricultural production, and reducing environmental impacts. Precision farming uses different types of technologies to measure, observe, and act upon factors that are relevant to the growth of crops and livestock. These can range from big data, GPS, robotics, sensors, and drones, to low-tech measures such as using bottle caps for applying the right amounts of fertilisers to individual plants. Aiming to optimize crop or livestock production, precision techniques include measuring, modelling, and responding to (site-specific) data, including weather forecasts, soil properties, soil water content, pests, and weeds.

Sustainable intensification
Sustainable intensification is a recently developed concept that is understood in different ways by its critics and supporters. A common understanding is that it denotes the principle of increasing or maintaining the productivity of agriculture on existing farmland while at the same time, reducing its environmental impacts. Understood in this way, SI designates a goal for the development of agricultural systems but does not, a priori, favour any particular agronomic route to achieve it. It may involve the intensification of different types of agricultural inputs (e.g. of knowledge, biotechnologies, labour, machinery) and apply these to different forms of agriculture (e.g. livestock or arable; agroecological or conventional). Forms of intensification that can be called sustainable intensification must lower environmental impacts and land use, relative to yields. However, for some, to merit the term 'sustainable' social, economic, and ethical criteria must also be considered.

The Food and Agriculture Organisation (FAO)
The Food and Agriculture Organisation is a specialised agency of the United Nations. It is dedicated to leading international efforts to defeat hunger worldwide.

Yield gap
A yield gap is the difference between the actual productivity of a given area of farmland and the maximum productivity that could in principle be achieved using agricultural practices, resources and technologies that are currently available. The best yields that can be obtained locally depend on the capacity of farmers to access and use, among other things, land, seeds, water, nutrients, pest management, soils, biodiversity, and knowledge. Yield gaps are studied and measured at various scales - from the farm through to the national and global levels.

Recommended resources

To learn more about this topic we recommend:

- Literature review (open access): Conceptualising Fields of Action for Sustainable Intensification
- Literature review (open access): Sustainable Intensification – "Oxymoron" or "third-way"?
- FCRN report (open access): Sustainable intensification in agriculture
- Book (paywall): Sustainable Intensification of Agriculture - Greening the World's Food Economy

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