Approaches to sustainable agriculture

Exploring the pathways towards the future of farming

Barbara Pia Oberč and Alberto Arroyo Schnell

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

Ministry of Agriculture, Nature and
Food Quality of the Netherlands

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Available from: IUCN (International Union for Conservation of Nature)
European Regional Office
Boulevard Louis Schmidt 64
1040 Brussels
Belgium
Tel: +32 2 732 82 99
Fax: +32 2 732 94 99
brussels@iucn.org
www.iucn.org/resources/publications

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Forewords

Janusz Wojciechowski, Commissioner for Agriculture – European Commission

I would not be surprised if the kind reader – once having taken a look at the title and the table of contents – would save reading this foreword for the end and jump directly to one of the agricultural terms described in this report. Many of these approaches are frequently advocated as an effective means to progress towards more sustainable farming in Europe.

It is my hope and expectation that this report will contribute to the current **public debate** and bring valuable input to implement the vision of sustainable agriculture, by clarifying the many terminologies and approaches associated with sustainable agricultural practices.

The European Union is strongly committed to sustainable agriculture. We are, therefore centering our focus on delivering an ambitious economy-wide framework to effectively address the interdependent environmental and climate challenge in an integrated manner.

The **European Green Deal** puts **sustainability** at the heart of discussions about the future of Europe. It constitutes our **new growth strategy**, which aims to transform the European Union into a fair and prosperous society with a modern, resource-efficient and competitive economy with zero net greenhouse gas emissions in 2050. It will accelerate and underpin the **ongoing transition** in all sectors towards a sustainable Europe.

In the agricultural context, the European Green Deal aims to expand the "**use of sustainable practices**, such as precision agriculture, organic farming, agroecology, agro-forestry and stricter animal welfare standards". It draws particular attention to "measures such as **eco-schemes**, addressed to reward farmers for improved environmental and climate performance, including managing and storing carbon in the soil, and improved nutrient management to improve water quality and reduce emissions".

However, the European Green Deal does not only aim to improve the sustainability of production methods in the EU farming sector, but it also aims to **transform Europe's food systems** in the broadest sense. The COVID-19 pandemic has put the need for such a transformation in sharp focus; sustainability thus needs to be linked to effectively defending EU **farmers** who have a pivotal role to play in the transition to sustainable food systems. This includes their better integration in the supply chain and building their resilience to external shocks.

The new **Farm to Fork Strategy** aims at reducing the environmental and climate footprint of the EU food system, strengthening its resilience, ensuring food security, facilitating the transition towards competitive sustainability from farm to fork and making use of new business opportunities. It draws our roadmap towards **fairer, healthier and environmentally friendly food systems in the EU by 2030**.

The European Union wants to continue to lead by example and offer others a useful model for a transition towards sustainable agriculture. It is an attempt to demonstrate that a socially fair transition to sustainable agriculture is not only possible but also opens many economic opportunities. Succeeding in this transition is the challenge we have taken upon ourselves.

European food is well-known for being affordable, safe, nutritious and of high quality. Still, we need to make further efforts so that it will become a global standard for sustainability as well.

The **Farm to Fork Strategy** and the **Biodiversity Strategy for 2030**, both address the need to reduce the use and risk of pesticides, the use of antimicrobials and fertilisers in agriculture, increase the share of organic farming and to enhance the share of landscape elements and set aside for nature. These objectives have been translated into **quantitative, aspirational EU flagship targets**.

The **Common Agricultural Policy** (CAP) has been a central instrument for rewarding and supporting farmers who embrace more sustainable farming practices but without undermining food security.

The **new CAP** aims to provide strong support for sustainable practices as well as for **farm income**; because viable farms are a prerequisite for more sustainable agricultural production. Promoting agro-diversity and better managed supply chains are also elements contributing to sustainability that will increase farmers' resilience to the aforementioned exogenous shocks.

The new voluntary '**eco-schemes**' that we are proposing are a good example of a significant tool to support many environmental practices – as well as other approaches or specific practices relevant to climate change, adaptation, management of natural resources, and biodiversity. These new eco-schemes will also offer opportunities to a large number of farms to deliver better environmental and climate results, climate resilience and reduce and optimise the use of inputs.

But we will need to do more.

Farmers will need to **radically transform their production methods** and make the best use of technological, digital, and space-based solutions to usher in the new agricultural transition.

Research and innovation, **advisory services**, investments, **digitalisation** and new technologies will be among the key enablers driving the transition.

The challenges and opportunities are only just starting.

I am convinced that in Europe, the Farm to Fork Strategy, the Biodiversity Strategy and the CAP reform provide a comprehensive answer to some of the **environmental, social and economic challenges of our times**.

In all of this we nonetheless must remember that while agriculture and farmers are indispensable partners for making the world and its food system more sustainable, for this to happen we also need agricultural policy that is first and foremost friendly to the farmers.

Luc Bas, Director – IUCN European Regional Office

Agriculture is and will continue to be a **core issue for the conservation sector**.

A primary form of land use and integral to our survival, agriculture is also one of the biggest drivers of biodiversity loss. This occurs through land use change in the first place, and can sustain a negative impact through unsustainable agricultural practices.

The importance of agriculture and our reliance on our food system have been highlighted during the recent COVID-19 outbreak. While much of the economy temporarily ground to a halt, farmers and grocers continued their essential services of putting food on our tables.

At the same time, the COVID-19 outbreak shone a light on the persisting crises underpinning our global, interconnected world. The **crises of nature loss and climate change threaten our survival** far more profoundly and, if left unsolved, will also continue to bring about new crises. Zoonotic diseases such as the novel coronavirus are a direct result of our invasive and destructive relationship with nature. If we do not transition to a more sustainable system with the environment at its heart, we will surely risk further social and economic collapses.

The food system as we know it today is global and interconnected, and is as much affected by changes in nature and the climate as it is reliant on the important ecosystem services and natural resources that they provide. As this food system is also a key contributor to nature loss and climate change, it is no longer a matter of discussion whether transitioning to a more sustainable system is desirable. We know that **we must set ourselves on the path to sustainable agriculture**, and fast – the question is not if, but how?

This paper outlines some of the main approaches to sustainable agriculture that we know today. Each of these is striving towards a more sustainable system, albeit in a different way. Clarifying the landscape of the different approaches for sustainable agriculture that are possible and indeed already practiced is an important exercise in raising awareness and their profile among prospective practitioners and policy makers. **We need to have a better understanding of the tools already available** to us, including what crucial aspects they have in common as well as the challenges they face and opportunities they present.

Our path towards sustainable agriculture has to be a common effort: from international and national authorities and decision makers, to all stakeholders along the food value chain, producers, retailers, consumers and also environmental actors such as NGOs. With the enhancement and sharing of knowledge and perspectives, we can better band together towards a common vision and transformation of our food system. **This paper is an important step on the path** towards this goal, and we hope that it may serve as an important tool in its own right.

Because for us, **the International Union for Conservation of Nature, it is fundamental to find**

solutions to ensure the future of agriculture is sustainable, for both society and nature. In this spirit, we organised, together with the European Commission, the round tables on the green architecture of the EU Common Agricultural Policy (CAP), bringing together farmer and environmental organisations to discuss ways to enhance the environmental performance of the future CAP. And it is also in this spirit, that we now present this paper, to help build a common understanding of the terminology relating to sustainable agriculture. IUCN will continue to pursue this positive collaboration with all relevant actors: the European Commission, EU Member States, and other key stakeholders. Only together can we succeed in achieving sustainable agriculture for the future.

Executive summary

The high amount of land used for cultivation and livestock farming has dramatically shaped landscapes in Europe and throughout the rest of the world. **Agriculture is a fundamental human activity that intrinsically depends on nature and at the same time poses a threat to it. Thus, sustainability has emerged as a necessity in future agricultural policy and practice.** Sustainable agriculture will need first and foremost to consider two inseparable, intertwined societal priorities – preserving the environment and providing safe and healthy food for all. It will be necessary for all sectors and stakeholders involved in the food system and nature conservation to find a common path for the future which embraces these two priorities.

With many different attempts to find solutions and pathways for sustainable agriculture already underway, there is a growing number of terms applicable to sustainable agriculture. Rather than helping to advance meaningful action, this broad number of terms can lead to confusion, cloud understanding, and divert focus from what is relevant. In this context, we hope that **this report can help overcome an important roadblock by shedding some light on the different terms relating to sustainable agriculture**. Structured as a factual collection of information based on existing literature, this report can thereby serve as a helpful tool and reference, providing a common footing for the stakeholders involved and helping move the debate along.

This report examines a number of approaches to sustainable agriculture, as well as supporting activities. The approaches include: *agroecology, nature-inclusive agriculture, permaculture, biodynamic agriculture, organic farming, conservation agriculture, regenerative agriculture, carbon farming, climate-smart agriculture, high nature value farming, low external input agriculture, circular agriculture, ecological intensification, and sustainable intensification*. The main supporting activities examined are: *genetic improvement, precision farming, mixed farming systems, integrated farming tools, pasture-based and free-range farming, landscape and ecosystems approaches*, and supporting socio-economic activities including *community-supported agriculture, urban farming, and agritourism*.

Although each may consider sustainable agriculture from a different angle, **the approaches examined in this report would appear to share more similarities with each other than with conventional agricultural approaches**. **The approaches all share the common goal of striving for sustainability, which includes environmental aspects but also socio-economic considerations**. Furthermore, **many of the approaches share similar environmentally-friendly practices**, including: *crop rotation, cover and companion cropping, mixed and intercropping, the reduction of synthetic pesticide and mineral fertiliser use, no or minimal tillage, lower livestock densities, managed and free range grazing,* as well as: *crop diversification, mixing farming and forestry, mixed crop and animal farming, nutrient balancing, recovery and reuse, and the inclusion of landscape elements such as hedgerows and flower strips*. Without being exhaustive, we may nevertheless conclude that **all the practices listed can be considered "sustainable agricultural practices"**.

Many approaches also face common challenges. Some of these relate to uptake and scalability, some to costs and profitability. Approaches with stronger markets already in place have seen more success. Regardless, it is important to keep in mind the recognition by scientists that nature and its contributions to people can be safeguarded only by transformative change to a sustainable global economy. In this context, **potential costs and/or a reduction in profitability might be mitigated through public support or private investments in a transition towards sustainable land use; the short-term savings of inaction will otherwise likely be outweighed by resultant longer-term societal and material costs**. A crucial factor underpinning another common challenge, related to knowledge, is the **lack of common metrics and indicators**. A lack of quantitative evidence of the benefits of these approaches will convince neither farmers, consumers, nor policy makers to adopt and promote them. With respect to the environmental component of sustainability, **some approaches might have difficulties giving all crucial environmental aspects the same level of consideration – i.e. soil, water, biodiversity, and the climate** – which in some cases could lead to perverse outcomes for one or another aspect. In any case, we should keep in mind that true environmental sustainability would need to consider and strive for the better state of all key aspects in a balanced, integrated manner.

Each of the approaches described in this report addresses sustainable agriculture from a somewhat different angle. **Each of these approaches, therefore, might be valid in a given set of specific circumstances.** While the approaches described in **this report focus on *how* to produce food,** the **spatial considerations, or *where*** (is this approach best suited for the landscape and environmental conditions in which it would be implemented in?) as well as the **temporal considerations, or *when*** (will implementing this approach mean this environment is better off than before?) need to be considered as well. Other considerations relating to social and economic sustainability will also be fundamental when choosing what approach to implement, in particular ***how much* we produce** (considering the immense amounts of food waste we are witness to today) and ***what* we produce** (considering what informs and drives the demand for healthy and nutritious food).

These last two questions also reflect the fact that **our food system as we know it today is global. The many interdependencies and issues along the global food value chain should be acknowledged and further explored** in order to arrive at practical and actionable ways by which to set in motion a transition towards sustainable agriculture. This will include looking into global consumption patterns, what exactly impacts demand, our key trade flows, and linked to all of this, the externalities and ecological footprint of our global food system, among other issues. **The COVID-19 crisis, for instance, has shown some interesting examples of how global supply chains may have given way to more local production and consumption chains in food systems.**

It is in this context that we need to focus on sustainable agriculture, where the most striking fact arises: **we do not have a common vision for what sustainable agriculture should look like in the future**. This is a fundamental question, considering the main societal goal for agriculture to produce food, the necessary use of land for this purpose, and the negative impacts that this activity can have on the environment. **This report shows that different approaches exist, that they have a number of important commonalities, but also that their diversity is a strength in itself.**

When it comes to implementation, the choice of approach depends very much on local contexts and specific priorities. **The challenge for policymaking is to enable dialogue and create the (market or regulatory) environment that will help prioritise according to local contexts, helping land managers follow the societally desired path**.

Underpinning all of this and helping to inform these choices is the need for common metrics to ascertain and monitor the environmental performance of the various approaches, which are currently lacking. Considering that the production of healthy food at affordable prices with environmental protection at the core is crucial for our survival as a species, addressing these challenges is the most important step we need to take for our common future, right now.

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Glossary

Terms related with sustainable agriculture	**Cross-references in the document**
aeroponics	*See* Chapter 3.14/4 (Supporting Socio-Economic Activities)
alley cropping	*See* Chapter 3.8 (Mixed Farming Systems)
alternate wetting and drying (AWD)	*See* Chapter 3.9
animal welfare	*See* Chapter 3.5/4 (Pasture-based and Free-range Farming)/5
agritourism	*See* Chapter 4 (Supporting Socio-Economic Activities)
agrobiodiversity	*See* Chapter 3.1/3.2
agroecology	*See* Chapter 3.1
agroforestry	*See* Chapter 3.1/3.3/3.7/3.9/4 (Mixed Farming Systems, Landscape and Ecosystems Approaches)
agrisilvicultural systems	*See* Chapter 4 (Mixed Farming Systems)
agrosylvopastoral systems	*See* Chapter 4 (Mixed Farming Systems)
base broadening	*See* Chapter 3.14/ 4 (Genetic Improvement)
biodynamic agriculture	*See* Chapter 3.4
biodynamics	*See* Chapter 3.4
biological control	*See* Chapter 3.1/3.4/3.11
biotechnology	*See* Chapter 3.14 / 4 (Genetic Improvement)
blooming/flower strips	*See* Chapter 3.5/3.10/5
buffer strips	*See* Chapter 3.8
cage-free management	*See* Chapter 3.5
carbon capture	*See* Chapter 3.6/3.7/3.8/3.9/ 4 (Mixed Farming Systems, Supporting Socio-Economic Activities)
carbon farming	*See* Chapter 3.8
carbon sequestration	*See* Chapter 3.6/3.7/3.8/3.9/ 4 (Mixed Farming Systems, Supporting Socio-Economic Activities)
cell grazing	*See* Chapter 3.10
circular agriculture	*See* Chapter 3.12
climate smart agriculture	*See* Chapter 3.9
community gardens	*See* Chapter 4 (Supporting Socio-Economic Activities)
community supported agriculture (CSA)	*See* Chapter 3.4/4 (Supporting Socio-Economic Activities)
companion crops	*See* Chapter 3.5
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conservation agriculture	*See* Chapter 3.6
conservation tillage	*See* Chapter 3.1/3.13
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conventional agriculture, conventional farming practices	*See* Chapter 3.5/3.6/3.7
corridor management	*See* Chapter 4 (Landscape and Ecosystem Approaches)
cover cropping	*See* Chapter 3.1/3.3/3.4/3.5/3.6/3.7/3.11/3.13
crop diversification	*See* Chapter 3.11
crop protection	*See* Chapter 4 (Integrated Farming Tools)

crop residue	*See* Chapter 3.6/3.12
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Demeter certification	*See* Chapter 3.4
direct seed placement	*See* Chapter 3.6/3.8/3.13
diversification	*See* Chapters 3.1/3.5/3.11/3.14/5
diversified farming	*See* Chapter 4 (Mixed Farming Systems)
domestication	*See* Chapter 3.14/ 4 (Genetic Improvement)
drought management	*See* Chapter 3.9
dual-purpose food-feed crops	*See* Chapter 3.12
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ecological farming	*See* Chapter 3.4
ecological intensification	*See* Chapter 3.13
ecosystem-based adaptation (EbA)	*See* Chapter 3.13
ecosystems approach	*See* Chapter 4 (Landscape and Ecosystem Approaches)
ecosystem management	*See* Chapter 3.9
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hugelkultur	*See* Chapter 3.3
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industrial agriculture, industrial farming practices	*See* Chapter 3.5/3.9/3.10/4 (Pasture-based and Free-range farming)
integrated crop-livestock systems, integrated crop-livestock-forestry systems	*See* Chapter 3.9/4 (Integrated Farming Tools)
integrated crop management (ICM)	*See* Chapter 4 (Integrated Farming Tools)
integrated farming	*See* Chapter 4 (Integrated Farming Tools)
integrated farm management (IFM)	*See* Chapter 4 (Integrated Farming Tools)
integrated farming systems (IFS) / integrated food and farming systems (IFFS)	*See* Chapter 4 (Integrated Farming Tools)
integrated farming tools	*See* Chapter 4 (Integrated Farming Tools)
integrated (plant) nutrient management	*See* Chapter 3.1/ Chapter 4 (Integrated Farming Tools)
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water retention	*See* Chapter 3.3/3.7/3.9
WWOOFing	*See* Chapter 4 (Supporting Socio-Economic Activities)
whole farm planning	*See* Chapter 3/3.1/3.2/4 (Precision Farming)
whole system approach	*See* Chapter 3.12
windbreaks	*See* Chapter 3.1/3.8/4 (Integrated Farming Tools)
wooded pastureland	*See* Chapter 3.10
woodlots	*See* Chapter 3.1
zero-grazing	*See* Chapter 3.9

Acronyms

CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CGIAR	Consultative Group for International Agricultural Research
COP	Conference of the Parties
COVID-19	Coronavirus disease 2019
DG AGRI	The European Commission’s Directorate-General for Agriculture and Rural Development
EC	European Commission
ECPA	European Crop Protection Agency
EEA	European Environment Agency
EISA	European Initiative for Sustainable Development in Agriculture
EIP-AGRI	The agricultural European Innovation Partnership
EU	European Union
EUPAG	IUCN’s EU Policy Advisory Group
FAO	Food and Agriculture Organization of the United Nations
FCRN	Food Climate Research Network
FOLU	Food and Land Use Coalition
GHG	Greenhouse Gases
GMO	Genetically Modified Organism
HNV	High Nature Value Farming
IAEA	International Atomic Energy Agency
ICT	Information and Communications Technology
IEEP	Institute for European Environmental Policy
IFAD	International Fund for Agricultural Development
IFOAM	International Federation of Organic Agriculture Movements
IIED	International Institute for Environment and Development
ILEIA	Information Centre for Low External Input and Sustainable Agriculture
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	International Panel on Climate Change
IPM	Integrated Pest Management
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
LEAF	Linking Environment and Farming
LED	Light-Emitting Diode
LEIA	Low External Input Agriculture
MFS	Mixed Farming Systems
SDG	Sustainable Development Goals
TPC	Third Party Certification
TYFA	Ten Years for Agroecology
UNEP	United Nations Environment Programme
URGENCI	International Network for Community Supported Agriculture
USDA	United States Department of Agriculture
WCED	World Commission on Environment and Development
WFP	World Food Programme
WUR	Wageningen University and Research
WWOOF	World Wide Opportunities on Organic Farms

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1. Introduction

Since the beginning of agriculture circa 10,000 B.C., the high proportion of land for cultivation and raising animals has dramatically shaped the landscapes in Europe and the rest of the world. This trajectory continues, with the Food and Agriculture Organization of the United Nations (FAO) projecting a substantial increase in worldwide food production during the upcoming years, especially in developing countries (FAO, 2011). Agriculture is a fundamental human activity that depends intrinsically on natural processes, including soil fertility, water recycling, and pollination, and both nature and agriculture are increasingly suffering the negative impacts of climate change (EEA, 2019). At the same time, unsustainable agriculture also poses a major threat to biodiversity (Secretariat of the Convention on Biological Diversity, 2014), negatively affects the state of our soil and water, and is an important contributor to climate change (Jia et al., 2019). In the European Union (EU), agriculture is the activity most frequently cited as negatively impacting the state of nature (EEA, 2015). Globally, agricultural expansion continues to be the most widespread form of land use change (IPBES, 2019).

By acknowledging the major impact of agriculture concurrent with the environmental crises we face, the concept of "sustainable agriculture" emerges as the necessary way forward. This is also important in the context of the nature-based solutions as they have been defined: "*actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits*" (Cohen-Shacham et al., 2016).

The path towards sustainable agriculture involves the consideration of two key societal priorities: preserving the environment, and providing safe and healthy food for all. These priorities are both intertwined and essential in order to find a common path towards a sustainable future. However, the abundance of terminology connected with sustainable agriculture – be they concepts, approaches, or practices – represents a challenge in itself. A myriad of terms are continuously popping up and being reinvented, revised, or promoted. This abundance of terminology often becomes the subject of debate and disagreement, delaying the effective transition to truly sustainable forms of agriculture. Rather than help contribute to an evolving and fruitful discussion that can lead to meaningful action, the debate over terminology instead too often can add to the confusion, cloud understanding and divert attention and focus elsewhere.

We do not have endless time for debate – we have less than ten years until 2030, by which time we should have reached the globally agreed to, UN-mandated Sustainable Development Goals. What is needed now is action and meaningful progress towards finding a common path and vision to transitioning to a form of sustainable agriculture which benefits people, food production, and nature. In this context, *the main objective of this report is to try to shed some light on the different terms related to sustainable agriculture*, which includes outlining the key approaches that have been conceptualised and/or implemented around the world.

This report is a structured collection of objective information based on existing literature. Furthermore, the content of the report has been reviewed by numerous key agricultural experts from various backgrounds including the private sector, environmental NGOs, and academia. We hope that this report will serve as a helpful tool for future discussions, as well as potentially a referential document for the key approaches, concepts, and practices being considered by practitioners, researchers, and policy makers today.

We also hope that the timeliness of this report will help stimulate discussion and expedite action along the path to 2030, especially within the context of the many upcoming processes and events related to the future of our planet. This includes the upcoming IUCN World Conservation Congress, the COP 15 of the Convention of Biological Diversity and the development of the post-2020 global biodiversity framework, as well as the fulfilment of the UN Sustainable Development Goals (SDG)s and the implementation of the Paris Agreement for Climate Change. It also involves the discussion and implementation of key policies and initiatives at the EU level, such as the Multiannual Financial Framework (the EU Budget), the EU Common Agricultural Policy (CAP), and relevant components of the new EU Green Deal such as the EU Biodiversity Strategy to 2030 and the Farm to Fork Strategy.

IUCN and sustainable agriculture

During the previous IUCN World Conservation Congress in 2016, the Hawai'i Commitments recognised the need to "transform our complex food production / consumption systems so that they do not degrade the biodiversity and ecosystem services on which they depend" (IUCN, 2016). This recognition led to a mandate for IUCN to work towards promoting sustainable agriculture, both at the global level as well as in the EU, through the IUCN European programme. Since then, IUCN has been increasingly involved in issues relating to agriculture. Underpinning our work towards promoting sustainable agriculture, there is a need to help to chart out a common path and vision for what sustainable agriculture could and indeed should look like. To this end, IUCN's paper "Towards Sustainable Agriculture" (EUPAG, 2018) served as a structured first compilation of key evidence regarding sustainable agriculture, aiming to contribute to the discussion.

Building on IUCN's convening role in bringing together a diversity of actors on matters relating to nature conservation, we have been increasingly involved in discussions with a variety of stakeholders on the subject of sustainable agriculture in the global, EU, and local contexts. Together with the European Commission's Directorate-General on Agriculture and Rural Development, IUCN has been organising a series of roundtables on the Green Architecture of the Common Agricultural Policy (DG AGRI and IUCN, 2018), bringing together farmer organisations and environmental NGOs to discuss potential ways forward. While this is a promising development, much more remains to be done, not least of which is agreeing on the basis for further discussion - what approaches or practices can help us to move towards a more sustainable model of agriculture. Along with this report, which we hope will provide some of this basis for further discussion, a second publication, "Common grounds: restoring land health for sustainable agriculture", has been prepared by IUCN in parallel, to capture some key lessons on land health at the global scale. 2021 will launch the new IUCN Global Programme 2021-2024. The priorities for this new Programme have already been drafted, and include a focus on agriculture in the context of managed landscapes. This is also complemented with an IUCN Union-wide strategy specifically on the topic of agriculture.

The COVID-19 pandemic has caused delays for many of the aforementioned initiatives and discussions. The momentum towards greater nature and climate action that existed in the build-up to 2020 was lost due to shifting priorities in the face of this global pandemic. Yet it is during such a situation that society must work firmly towards the aforementioned goals. The COVID-19 crisis has unveiled just how global and fragile our current systems are, and that global, collective, firm action is absolutely vital to our collective health and prosperity. We need to harness the lessons and momentum from this crisis to fully understand both our dependence on nature for our survival, and the need to listen to science when making critical decisions. Only by doing this may we stand a chance at avoiding further, potentially irreparable collapses in our natural, social, and economic system in the run-up to our goalpost years of 2030 and 2050.

This report does not endeavour to be all-encompassing or an in-depth analysis of every approach, concept, or practice. This is particularly so for practices, of which we acknowledge there are many, but also for the approaches, of which many continue to evolve to this day. We have included a glossary where all cross-references of all terms within the report can be found. While considering all aspects of sustainability (economic, social and environmental), this report focuses foremost on the environmental aspects, not by ranking but by pointing out its relevance due to the previously long-ignored environmental pressures by most of our current production systems. The report has been prepared with a focus on Europe in mind; however, its examples, findings, and relevance transcend this geographical scope. The report does not aim to initiate an ontological discussion about the definitions or use of the different terminology described within the following chapters, as that would be contrary to its intention to focus the discussion on more pertinent matters relating to sustainable agriculture; we have only suggested a way forward to clarify this terminology that we hope is useful. While we have tried to summarise the key findings in the conclusions, the report does not aim to provide opinions, a vision, or a set of policy recommendations for sustainable agriculture. We have instead tried to compile a common, baseline understanding, to be able to build meaningful consensus among stakeholders around the key terms and concepts, which surround sustainable agriculture.

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2. What is sustainable agriculture?

The upcoming IUCN publication "Common grounds: restoring land health for sustainable agriculture" (2020), which shares a number of authors from the Secretariat of IUCN in Gland and Brussels with the present report, is the basis for this chapter. The definition of sustainable agriculture is discussed in detail in that publication.

Although there is no unified agreed-upon definition of sustainable agriculture, we can say that the idea of sustainable agriculture should be in agreement with the definition of sustainable development. Therefore, and as outlined in the UN's 1987 Brundtland report (WCED, 1987), sustainable agriculture should be able to meet the current needs of society without compromising the ability of future generations to meet their own needs. It should take into account environmental, social, and economic sustainability, which constitute the three central pillars of sustainable development.

Consistent with this definition, and relating to these three pillars, the FAO defines sustainable agriculture as the "*management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development… conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable*" (FAO, 1988). Based on this, the FAO has proposed five principles (FAO, 2014) for sustainable agriculture that capture all three pillars, namely: 1) improving efficiency in the use of resources, 2) conserving, protecting and enhancing natural ecosystems, 3) protecting and improving rural livelihoods and social well-being, 4) enhancing the resilience of people, communities, and ecosystems, and 5) promoting good governance of both natural and human systems.

In the same vein, the nine specific objectives (European Commission, 2018) of the 2018 proposal for the future EU Common Agricultural Policy for the period 2021-2027 are split evenly between the three pillars; there are three economic objectives (*ensuring a fair income to farmers, increasing competitiveness, rebalancing the power in the food chain*), three environmental objectives (*climate change action, environmental care, preserving landscapes and biodiversity*), and three social objectives (*supporting generational renewal, vibrant rural areas, protecting food and health quality*). In another attempt to define sustainable agriculture, the United Kingdom's Royal Society (2009) enumerates four principles for agricultural sustainability: persistence, resilience, autarchy and benevolence. It states that any approach is unsustainable if it depends on non-renewable inputs, cannot consistently and predictably deliver desired outputs, can only do this by requiring the cultivation of more land, and/or causes adverse and irreversible environmental impacts.

In principle, there should be a consensus on how the three pillars of sustainability apply to sustainable agriculture, although the extent to which the approaches to sustainable agriculture take into account or focus on one pillar more than another may differ. Gliessman (2007), for instance, defined five levels for sustainable agriculture, wherein sustainable agriculture may be considered to lie along a continuum of increasing complexity, ranging from improving system efficiency and reducing inputs (level I), to redesigning systems according to ecological principles (level III), to the system being fully embedded in the social and economic pillars (level V). Concerns have been raised that, in this respect, sustainable agriculture often focuses too much on the lower levels of this continuum, while neglecting higher levels (Cook et al., 2015). At the same time, as Johan Rockström and Pavan Sukhdev concluded, all the SDGs are either directly or indirectly connected to sustainable and healthy food (Rockström & Sukhdev, 2016). They have also provided a hierarchy of sorts to frame the SDGs, with those relating to the biosphere (the environment) as the basis for all the others (see the so-called “the wedding cake” representation of the SDGs) (Rockström & Sukhdev, 2016).

Other ways to understand sustainable agriculture and the differences between approaches have been proposed; for instance, the debate between land sparing and land sharing (sparing areas exclusively for nature and intensifying agriculture on existing land vs. sharing our farmlands with nature by reviving small woodlands and integrating conservation measures on working land (Pearce, 2018)). While this kind of discussion may illustrate certain trends well, they also run the risk of applying simplistic terms to a complex issue. In this respect, all possible solutions need to be taken into account, as it is important to consider the particular context for a particular approach when determining its appropriateness and implementation.

In attempting to transition to sustainable agriculture, it is important to consider the entire food value chain beyond merely production, and to recognise that our food value chain is global. Issues such as consumption and trade are not independent from the discussion on agriculture. In this context, we must note that given the impacts on land, the issue of food waste, and a growing world population, we cannot ignore the question of *how much* we produce. Furthermore, given the agricultural sector’s impact on climate change and the need to provide healthy and quality food, we cannot ignore the question of *what* we produce, either. It is also crucial to consider that many areas have unique biodiversity or climate protection value that need to be considered, so it is also important *where* we produce. When introducing a new form of land use into a given area, one must consider what was there before, giving us the temporal question of *when,* as well. That said, for the purposes of this report, and to plant ourselves more squarely in the realm of agriculture, the question we primarily focus on in this report is that of *how* we produce.

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3. Approaches to sustainable agriculture

The number of terms that surround the subject of sustainable agriculture is substantial. It is not always easy to know what each term refers to - whether it is an approach, a practice, a set of related practices, an activity or tool, etc. Therefore, as the first step in the process leading to this report, we compiled a long list of all the terms related to sustainable agriculture. Nothing was left out, as this document is intended to be a referential one. While we had to make some choices regarding certain terms, in particular in what way to include them, we aimed for every term to ultimately be considered in an appropriate way and placed in the report. The full list of terminology we collected may be found in the Glossary, including all cross-references within this report.

We then took a step back, aiming to start from a relatively clean slate and without any preconceived notions about the terms we had collected. We carried out intensive desk research, analysing each term and its potential relationship with the others based on a review of information from existing literature (for which there is a large number of references throughout the report).

This exercise led to the identification of certain established terms that were specifically developed towards achieving a more sustainable agriculture, most of them with a special focus on the environment. All of these terms also had a strong philosophy or theory attached to them. This means that all of these approaches generally had a) clear principles, b) environmental, economic, and social objectives and c) had evolved as approaches in their own right over some time (i.e. agroecology or sustainable intensification) or were high on the policy agenda from their inception (i.e. carbon farming). Often these approaches may be applicable within a variety of production types and environments, or consider the whole farm / system in their design. In most cases they have practitioners, and sometimes a market / label already associated with them (e.g. organic farming). Although they could be varied in terms of scope (more "overarching" such as agroecology or sustainable intensification, or more "focused" such as permaculture or perhaps high nature value faming), a key unifying characteristic is the fact that they are all choices that may be made by farmers and will largely determine the way in which they manage their farm in the long term. With the previous criteria in mind, the following approaches were shortlisted for presentation in this report:

1. Agroecology
2. Nature-inclusive agriculture
3. Permaculture
4. Biodynamic agriculture
5. Organic farming
6. Conservation agriculture
7. Regenerative agriculture
8. Carbon farming
9. Climate-smart agriculture
10. High nature value farming
11. Low external input agriculture
12. Circular agriculture
13. Ecological intensification
14. Sustainable intensification

As previously stated, this list does not claim to be exhaustive; rather, it intends to be a means of clarifying the landscape of various terminologies associated with sustainable agriculture.

A second tier of activities were identified as playing a role in the context of sustainable agriculture. However, they were not all necessarily conceived specifically for use in sustainable agriculture. They also do not carry a "philosophy" for sustainable agriculture per se, but rather are tools that can be helpful in a number of cases – e.g. they can be implemented under a number of the approaches outlined in this chapter. These supporting tools and activities are described in the following chapter (Chapter 4).

The process of identifying these approaches included several consultations with experts early on. Specifically, a set of informal meetings were held to gain feedback and clarify what might be the most useful way to organise the information. These consultations occurred on a regular basis as the report developed. With each meeting, and each bit of feedback, the report evolved not only in terms of its content but, iteratively, also in its framing and scope. Furthermore, the preparation in parallel of the IUCN publication "Common grounds: restoring land health for sustainable agriculture" (2020), which shares a number of authors from the Secretariat of IUCN in Gland and the European Regional Office in Brussels, also helped to frame the scope and structure for both reports, ensuring consistency between the two.

Each approach included in this chapter is described via the following structure, for the sake of consistency:

- *Definition*: includes a short history of the approach (when and where it originated), an idea of its geographical scope and applicability within a certain environment or production type, and some elements of the definition (including its source);
- *Principles:* the "philosophy" behind the approach, the angle taken, and the key goals and priorities espoused (in case there are different ones, those are noted);
- *Practices*: a non-exhaustive list of examples of the practical use of the approach;
- *Challenges and opportunities*: beyond the potential challenges and opportunities as found in the literature, the approach is also evaluated, insofar as we are able to, in relation to the three sustainability pillars.

3.1 Agroecology

Definition

Agroecology **emerged as a concept in the 1930s, expanded as a science during the 1970s and 1980s, and became institutionalised and consolidated in the 1990s** (Wezel & Soldat, 2009; Silici, 2014). Its first definition, as the application of ecology in agriculture, can be traced back to 1928, in a publication by Basil Bensin, a Russian agronomist who later worked in the United States (Wezel & Soldat, 2009). The concept was soon taken up by prominent ecologists and agronomists in France, Germany, and the Netherlands, and then the world over, evolving its scope. Over time, the definition for agroecology has developed from a narrower definition, based on ecological principles, to one which incorporates socio-cultural aspects. Now a well-known approach for sustainable agriculture, according to the FAO (2019), agroecology has been variously defined as a scientific discipline, a set of farming practices, a social movement, or all three. As a science, agroecology involves the holistic study of agro-ecosystems. As a practice, it seeks to boost the resilience and the ecological, socio-economic and cultural sustainability of farming systems, and as a movement, it seeks a new way of considering agriculture and its relationship with society (Silici, 2014). Agroecology Europe breaks this down in its definition (Agroecology Europe, n.a.), stating that "*as a science, it (agroecology) gives priority to action research, holistic and participatory approaches, and transdisciplinarity that is inclusive of different knowledge systems. As a practice, it is based on sustainable use of local renewable resources, local farmers' knowledge and priorities, wise use of biodiversity to provide ecosystem services and resilience, and solutions that provide multiple benefits (environmental, economic, social) from local to global. As a movement, it defends smallholders and family farming, farmers and rural communities, food sovereignty, local and short food supply chains, diversity of indigenous seeds and breeds, healthy and quality food*".

Today's visions of agroecology thus integrate transdisciplinary knowledge, farmers' practices, and social movements, while recognising their mutual interdependence (based on the definition from the FAO's High Level Panel of Experts on Food Security and Nutrition (FAO, 2017)). In 2012, France launched its "agroecology project" with the aim of achieving a transition to agroecology through an integrated approach, involving its three dimensions: the economic, environmental, and social (Larbodière, 2016). As a systematic, **whole-farm approach, its elements can be applied to all farms and production types**. As arguably one of the oldest sustainable agriculture approaches, many other approaches to or concepts for sustainable agriculture have evolved from or are based on agroecology. For instance, of the approaches listed in this report, permaculture, biodynamic agriculture, organic farming, and conservation agriculture are all rooted in agroecology and/or incorporate agroecological principles or practices (Erisman et al., 2017; Silici, 2014).

Principles

According to the International Institute for Environment and Development (IIED) (Silici, 2014), based on several authors, the core principles of agroecology are the following:

1. Planning: Using a holistic approach, the agro-ecosystem is regarded as one, its health as a whole valued over the productivity of single crops. The farming system is to be harmonised with the productive potential and physical limits of the surrounding landscape.
2. Resource use: The nutrients and energy in the farm system must be recycled and optimised. This involves the recycling of biomass to optimise organic matter decomposition and nutrient cycling; minimising losses of energy, water, nutrients and genetic resources by enhancing the conservation and regeneration of soil, water, and agro-biodiversity; minimising the use of agrochemical or other applications with a negative effect on the environment and health; minimising the use of external, non-renewable resources, e.g. fossil fuels.
3. Field and landscape management: Enhancing biological interactions and synergies among the components of agrobiodiversity, promoting key ecological processes and services over focusing on individual species; diversifying species and genetic resources in the agroecosystem (at field and landscape level) over time. Enhancing functional biodiversity, managing and preventing, rather than controlling, pests and diseases; using local crop varieties and livestock breeds to enhance genetic diversity and adaptation; managing organic matter, and enhancing soil biological activity.

The FAO (2018), basing their findings on a series of FAO regional seminars on agroecology, proposed ten elements, or principles, of agroecology that could help guide countries on the path to sustainable agriculture at scale and to achieve the SDGs. As a tool, the ten principles can serve as a guide to policymakers, practitioners, and other stakeholders in planning, operationalising, managing, and evaluation agroecological transitions. The ten principles, divided among three main categories but remaining interlinked and interdependent, are the following:

- Diversity; synergies; efficiency; resilience; recycling; co-creation and sharing of knowledge (describing common characteristics of agroecological systems, foundational practices and innovation approaches);
- Human and social values; culture and food traditions (context features);
- Responsible governance; circular and solidarity economy (enabling environment).

Practices

Agroecology is designed and managed through the implementation of a structural and functional diversification of the biological components of production systems, such as intercropping, polycultures, crop-livestock integration, agroforestry, and multispecies livestock keeping (FAO, 2019).

According to the IIED (Silici, 2014), examples of agroecology in practice include:

- Conservation tillage: no or minimum tillage improves soil structure and organic matter;
- Mixing crops in a single plot, such as intercropping / polycultures: biological complementarities improve nutrient and input efficiency, use of space and pest regulation, thus enhancing crop yield stability;
- Crop rotation and fallowing: nutrients are conserved form one season to the next, and the life cycles of insect pests, diseases and weeds are interrupted;
- Cover crops and mulching: reduce erosion, provide nutrients to the soil and enhance biological control of pests;
- Crop-livestock integration: allowing for optimal nutrient recycling, beyond economic diversification;
- Integrated nutrient management: the use of compost, organic manure and nitrogen-fixing crops allows the reduction or elimination of the use of chemical fertilisers;
- Biological management of pests, diseases and weeds, such as integrated pest management, push and pull methods and/or allelopathy: decrease long-term incidence of pests and reduce environmental and health hazards cause by the use of chemical control;
- Efficient water harvesting, reducing the need for irrigation;
- Agroforestry: maximises the use of sunlight and other resources, maintains and improves soil fertility and structure, also modifying the microclimate for crops;
- Use of local resources and renewable energy sources, composting, and waste recycling: allows a reduction in the use of some external inputs such as synthetic and chemical pesticides and fertilisers, as well as reducing pressure on the natural resource base;
- Holistic landscape management: around the field (e.g. windbreaks, insect strips and living fences), across fields (mosaic of crop types) and at the landscape level (e.g. river buffers, woodlots, pastures).

Challenges and opportunities

Some **specific challenges** for agroecology are linked to its many interpretations. According to Wageningen University and Research (WUR) (Verhagen et al., 2017), agroecology is currently seeking to establish stronger links with agricultural policies. However, given its historical roots as an ecological movement coupled with its many interpretations, it may prove difficult for it to evolve into an overarching, holistic concept. It is also difficult to monitor its progress and uptake. According to the FAO (2019), agroecology, being neither a technology nor a single practice, is a heterogeneous, context- and location-specific application of ecological and social principles. The discussion, and indeed measuring, of uptake or adoption may therefore also be made more difficult by the fact that there are few registries of agroecological farms.

In terms of sustainability, agroecology is a holistic concept attempting to address all three pillars. The environmental pillar underpins agroecology's basis, while the approach has evolved to become an increasingly socially-oriented one as well. However, in terms of the economy, the context- and location-specific nature of agroecology, which makes it more challenging to measure its uptake, may also pose a challenge to it achieving economies of scale. Furthermore, the variety of interpretations of the approach results in a lack of clarity for consumers, and may pose difficulties to creating a market for agroecological products, if that would be a goal. Indeed, as the term 'agroecology' is not protected by law (IFOAM, 2019), the nearest active version of a market label under the approach is that of organic farming. The Ten Years for Agroecology (TYFA) project (Poux et Aubert, 2018) provided a scenario for transitioning to agroecology in Europe, with ten years as the timescale to launch a movement that would make this a feasible prospect by 2050. It is based on phasing out pesticides and synthetic fertilisers, redeploying natural grasslands, extending agro-ecological infrastructures, envisaging healthier diets, and meeting the food needs of all Europeans while still maintaining export capacity for certain products (cereals, dairy, and wine). As a result, it envisages the reduction of agricultural greenhouse gases (GHGs) by 40% compared to 2010, as well as the restoration of biodiversity and increased protection of natural resources. While the TYFA scenario outlines the technical feasibility of such a transition, it highlights the need to explore but does not delve into the socio-economic considerations and requirements for the 'just transition'. At the same time, work is underway with the aim to help understand the socio-economic and policy drivers and barriers for the further development and implementation of agro-ecological practices in farming systems (UNISECO, 2018).

3.2 Nature-inclusive agriculture

Definition

Nature-inclusive agriculture, or 'natuurinclusieve landbouw', is an approach to sustainable agriculture **stemming from The Netherlands, from a policy concept adopted by the Ministry of Economic Affairs in 2014** (Runhaar, 2016). Based on agroecological principles, nature-inclusive agriculture also considers the farming system as an agro-ecosystem, focusing on its sustainability. It seeks to optimise ecological processes for food production, integrating food production and natural capital in such a way that agriculture and nature can reinforce one another. The approach is in contrast, or comes as a response, to the current prevalent practices in agriculture, where agriculture and nature are seen as two different sectors/identities, reflected also in government instruments and economic (market) systems. The approach considers this separation between nature and agriculture as having negative consequences for the quality of nature and, eventually, for food production.

According to van Doorn et al. (2016), nature-inclusive agriculture may therefore be defined as "***the pursuit of a positive, reciprocal relationship between farm management and natural capital*** *(where food production is supported by natural processes and agriculture contributes to the perpetuation of these natural processes)*" or as "an economically viable agriculture system that optimally manages natural resources and provides a basis for sustainable business operations, including caring for ecological functions and biodiversity on or around the business i.e. farm". A key difference between this approach and agroecology, is that nature-inclusive agriculture seeks to become mainstream, whereas agroecology focuses much more conceptually on the local food chain and context (van Doorn et al., 2016). As a **whole-farm approach, nature-inclusive agriculture may be applied in any geographical terrain and for all sorts of production**, with specific practices proposed to be implemented for arable farming and dairy farming.

Principles

Nature-inclusive agriculture aims to minimise the negative effects of agriculture on nature and to maximise the positive effects of nature on agriculture. It strives to achieve sustainable ecological and economic management. By sustainably using natural resources and ecosystem services, it aims to secure productivity on a long-term basis, minimise costs, and tap into the growing market demand for sustainably produced food, with the ultimate aim of catering to the undifferentiated mass market.

Nature-inclusive agriculture can be described based on the following three dimensions:

1. Biodiversity as the basis of a resilient agriculture and food system, making essential contributions to farm management (e.g. natural disease and pest control pollination, water supply and treatment, natural soil fertility, and good soil structure). This is called functional agrobiodiversity. Nature-inclusive agriculture maintains, strengthens, and uses this biodiversity and the ecosystem services that it offers the business/farm.
2. By making use of functional agro-biodiversity and ecosystem services, and with the aim of closing cycles towards reducing emissions, raw materials may be used more efficiently, and the business/farm's impacts on water, soil, air, and the natural environment may be minimised. This creates positive conditions for opportunities for specific species both on the farm and in the surrounding landscape.
3. Finally, there is the care for the landscape and the specific species on the farm. By constructing and maintaining landscape elements, farms can incorporate a green infrastructure that is vital for flora and fauna. Landscape elements also have the function of strengthening functional agro-biodiversity for the business/farm. Such management practices ensure the continued existence of, for instance, meadow and field birds and other farmland species (Erisman et al., 2017; van Doorn et al., 2016).

Nature-inclusive agriculture refers to practices that:

- Strive to close cycles as much as possible according to agro-ecological principles, ensuring a greater diversity of organisms and a greater interdependence with local natural capital instead of external sources;
- Strive for mutual reinforcement between financial results and ecological aspects, integrating both into the business/farm style and strategy;
- Encourage innovation and make long-term investments in their natural capital;

- Are attractive for large groups of farmers and can therefore become "mainstream" in the sector (van Doorn et al., 2016).

Practices

Sanders and Westerlink (2015) have identified effective measures to take as part of 'natuurinclusieve landbouw', of which some examples include:

- Lower cattle densities;
- Less inorganic fertilisation (max. 50-100 kg N/ha);
- Less use of chemical pesticides;
- Expanding and enlarging diversity of landscape elements (biotopes);
- (re)introduction of herb and flower edges;
- Decreased tillage.

The above measures require a greater adaption of and thus a greater commitment from the business (farm). Examples of measures with a lower threshold, which can also be implemented, include:

- Providing space for 'messy corners', i.e. areas for owls, hedgehogs, etc.;
- Non-turning tillage;
- Less use of fertiliser on edges of farming land;
- No mowing of ditch edges;
- Cleaning of ditches in phases;

Sanders and Westerlink (2015) express that the suitability of these measures varies widely and is, among other things, determined by the specificities of the landscape and of the farm - farmers must decide what best suits their circumstances. While it is possible to implement nature-inclusive agriculture in stages, or at different levels of adoption, the approach is more than the implementation of individual measures. It requires integrated management of soil and landscape quality, (food) production, and nature, both at the farm and the landscape levels.

Challenges and opportunities

Specific challenges and opportunities for nature-inclusive agriculture arise from the fact that, despite its similarities and links to agroecology and other more widely practised approaches, this approach is still quite new and in many ways at a relatively theoretical stage, ultimately aiming to achieve systemic, transformative change. At the same time, the practices it encompasses can be seen as 'very practical', helping further its ultimate aim of becoming more mainstream. Integration into policy and the value chain will, require quantifiable indicators and measurable impacts, whereas at the moment, as is the case for a number of approaches to sustainable agriculture, evidence linked to the approach is primarily qualitative. Further research and investment is required to get it to the stage where the concept is rolled out in practice.

In terms of sustainability, by integrating nature and agriculture, and through its aim to secure productivity, minimise costs, and generate more income, the approach aims to satisfy environmental as well as social and economic sustainability. As a business concept, with different levels of ambitions for different farms in different landscapes, the potential for this approach to bring about sustainable results with respect to all three "pillars" could be significant. While farmers can already start implementing the approach, full adoption (and the fulfilment of the approach's full potential) will require a transformation at the level of business operations and potential additional market development.

3.3 Permaculture

Definition

‘Permaculture’ is an approach and term **developed in the 1970s in Australia, by David Holmgren and Bill Mollison** (Lampeter Permaculture Group, 2006). It was inspired by Japanese farmer Masanobu Fukuoka’s *natural farming* philosophy, which recognises the need to consider social aspects in any truly sustainable system. While the term originally referred to ‘permanent agriculture’ this was expanded to stand also for ‘permanent culture’. Permaculture may, therefore, be thought of as more than a set of practices; it is rather a system of design based on whole-systems thinking and informed by a set of principles that serve to help farmers mimic the patterns and relationships found in nature.

In Mollison’s words, “*Permaculture is a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labour; and of looking at plants and animals in all their functions, rather than treating any area as a single product system*” (Mollison, 1991). He goes on to say, “*Permaculture…is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their food, energy, shelter, and other material and non-material needs in a sustainable way*” (Mollison, 1988). Holmgren’s more recent work (Holmgren, 2018) describes permaculture as a movement to redesign our ways of living to be more in tune with local surpluses and limits, active in the most privileged as well as most destitute communities and countries.

Principles

First described in Holmgren’s (2002) book *Permaculture: Principles and Pathways Beyond Sustainability*, there are 12 principles of permaculture (Holmgren, 2013):

1. Observe and interact: By taking time to engage with nature we can design solutions that suit our particular situation.
2. Catch and store energy: By developing systems that collect resources at peak abundance, we can use them in times of need.
3. Obtain a yield: Ensure that you are getting truly useful rewards as part of the work that you are doing.
4. Apply self-regulation and accept feedback: We need to discourage inappropriate activity to ensure that systems can continue to function well.
5. Use and value renewable resources and services: Make the best use of nature’s abundance to reduce our consumptive behaviour and dependence on non-renewable resources.
6. Produce no waste: By valuing and making use of all the resources that are available to us, nothing goes to waste.
7. Design from patterns to details: By stepping back, we can observe patterns in nature and society. These can form the backbone of our designs, with the details filled in as we go.
8. Integrate rather than segregate: By putting the right things in the right place, relationships develop between those things and they work together to support each other.
9. Use small and slow solutions: Small and slow systems are easier to maintain than big ones, making better use of local resources and producing more sustainable outcomes.

10. Use and value diversity: Diversity reduces vulnerability to a variety of threats and takes advantage of the unique nature of the environment in which it resides.
11. Use edges and value the marginal: The interface between things is where the most interesting events take place. These are often the most valuable, diverse and productive elements in the system.
12. Creatively use and respond to change: We can have a positive impact on inevitable change by carefully observing, and then intervening at the right time.

Permaculture, as a system of design, and an ecosystem-based approach, organises itself in layers (TC Permaculture, 2013; The Permaculture Research Institute, 2017a), understanding the farm as an ecosystem made up of component parts such as canopies, understories, shrub layer, ground cover, and so on. The approach also designs a farm in rings, or zones (Burnett, 2001), where 'Zone 0' is the house. 'Zone 1' the nearest to the house, where elements requiring most attention should be located (e.g. herbs, berries, compost for kitchen waste). 'Zone 2' is used for perennial plants that require less frequent maintenance. 'Zone 3' is where the main crops are grown. 'Zone 4' is kept as a semi-wild area used mainly for foraging, while 'Zone 5' is kept as a wilderness area, with little human intervention.

Practices

Following the 12 principles, practices falling under permaculture include:

- Implementing a systems approach, and closing the loop in terms of resources and nutrients: rainwater harvesting, composting;
- Making use of ecosystem services and biodiversity: pollinators (flowers, insect houses), nitrogen-fixers (clover), birds and bats (water features, food, habitat), etc.;
- Focusing on production: replacing lawns and grass with productive crops, growing perennial food plants;
- Building healthy soil: no tilling, no chemical and synthetic fertilisers or pesticides, mulching, cover crops;
- Practicing agroforestry, linking with the layering approach: trees provide not only fruit or nuts but a canopy and shelter, shrubs produce food and habitat for wildlife, ground covers and vines provide protection from soil erosion;
- Using animals for multiple functions, including: land management, food and fibre production, fertility management, and security. For instance, free-range chickens can keep pest populations down, turn the soil, manage weeds, etc. Other practices include managed grazing and silvopasture;
- Hugelkultur: burying wood to increase soil water retention;
- Managing water flow through keyline design;
- For some proponents, no pruning (stemming from *natural farming*).

Challenges and opportunities

Specific challenges relating to permaculture may be linked to questions concerning its commercial scalability. It is a relatively well-known approach, and could be considered quite successful, albeit at a smaller, more self-sufficient scale. There is much literature published on the subject and a number of permaculture networks and initiatives have spread all over the world (Whited et al., 2005; The Permaculture Research Institute, 2017b), with the majority of these initiatives being community-led initiatives and/or urban or home garden projects. The approach is also very knowledge-intensive, adding to its issues of scalability and possibility for widespread adoption. There is also criticism about the 'myth' that the approach requires little work and still produces significant yields, and criticism about the impracticality of certain practices. For instance, mulching has been criticised for requiring a lot of labour, providing an ideal habitat for pests, and keeping the soil cool which can hamper plant growth at the beginning of the season (European Permaculture Network, n.a.).

In terms of sustainability, with its focus on nature and its community-led applications, permaculture addresses environmental and social objectives well. In terms of economic sustainability, while teaching self-sufficiency is a useful objective in its own right, the approach is considered by many not to be scalable and as such, it is incompatible with respect to contributing to substantial and reliable food production (Stone, 2018), should that be the goal.

3.4 Biodynamic agriculture

Definition

Biodynamic agriculture is an approach to sustainable agriculture **founded by scientist and philosopher Dr. Rudolf Steiner** in the early 20th century (Biodynamic Association, n.a.). A highly mechanistic view of nature with respect to agriculture had developed in the 1900s, resulting in the growing adoption of synthetic fertilisers and pesticides and a number of farmers becoming concerned about the declines in the health and fertility of their soil, plants, and animals. At the request of these farmers, Dr. Steiner, who was known for his scientific-spiritual approaches, held a series of lectures on what became known as biodynamic agricultural practices in June, 1924 in the village of Koberwitz (then Germany, now Poland) (Biodynamic Association, n.a.). Following these lectures (Paull, 2011), biodynamic agriculture expanded rapidly in Europe. In 1928, the Demeter certification (Demeter, n.a.) was formed as a way to promote produce grown through biodynamic techniques, and remains the leading standard for biodynamic agriculture today (Rowe, 2018). As of 2015, of the 5000 Demeter-certified farms worldwide, 1500 are in Germany (Krause, 2015), while the approach has also gained popularity in the United States (Biodynamic Association, n.a.; Demeter USA, n.a.; Chhabra, 2017).

Biodynamic agriculture may be defined as an *ecological farming system that views the farm as a self-contained and self-sustaining organism*; farmers strictly avoid all synthetic pesticides and fertilisers, instead using living solutions for pest control and fertility, and set aside a minimum of 10% of the total farm's area for biodiversity (Demeter, 2012). Thus, biodynamic agriculture is considered to be a *holistic, ecological, and ethical approach to farming and food* in general, and the principles and practices of **biodynamics can be applied within different contexts, terrains, and production systems** (Biodynamic Association, n.a.), with the Demeter label enabling a market for biodynamic products.

Principles

Demeter, the leading organisation providing biodynamic certifications, outlines some key guiding principles (Demeter, 2016) relevant to the approach:

- Ecological: increasing soil fertility and vitality; adapting to regional conditions; creating conditions for healthy and beneficial food; treating animals with respect;
- Human development: following an interdisciplinary approach to continuously improving biodynamic methods, food quality,

and economic activity; fostering dialogue among practitioners and stakeholders; providing farmers with knowledge and skills to improve the quality of their work and boost their competitiveness; enabling decision-making in the Demeter association along the value chain;
- Economic value creation: using resources in a sustainable and innovative way towards closing the loop; making use of renewable resources; cooperating with ecological organisations, civil society, and companies from different industries but with shared values and goals for better regional value chains and international trade; carrying out all activities without harming or interfering with living organisms in the ecosystem; communicating and providing farmers and consumers with comprehensive and transparent information about the market and production conditions;
- Social relationship: being aware of and adapting to different local cultures, climates, and geographic conditions; lobbying for a pricing structure based on values that reflect the true costs of production; providing the conditions for fair and respectful interaction between all members of the value chain;
- Cosmic and spiritual impact: being receptive of personal spiritual abilities and sensitive to our environment and others, thereby striving for perception and enlightenment.

The key principles of biodynamics, according to a national Demeter website (n.a.), are:

- individuality of the farm;
- “living ground”;
- biodynamic preparations;
- compost and compost preparation.

Practices

Key practices, falling mainly under the ecological principles of biodynamic agriculture, include (Biodynamic Association, n.a.):

- Treating the farm as a living organism: each farm (or garden) is composed of many interdependent elements, which must be nurtured, harmonised, and managed in a holistic and dynamic way to support the health and vitality of the whole;
- Cultivating biodiversity: annual and perennial plants can all contribute to plant diversity, amplifying the health and resilience of the farm organism, with diversity in domestic animals beneficial to the land and providing a unique quality of manure;
- Integrating crops and livestock: supporting the creation and uptake of vital nutrients;
- Generating on-farm-fertility: composting, integrating animals, cover cropping, and crop rotation, to reduce or eliminate the need for imported fertilisers;
- Enlivening compost with biodynamic preparations (Demeter, n.a.): there are six preparations made from yarrow, chamomile, stinging nettle, oak bark, dandelion, and valerian, the application of which fosters the growth of beneficial bacteria and fungi and enriches the development of the compost, stabilising nitrogen and other nutrients, multiplying microbial diversity, and helping sequester carbon;
- Enhancing soil and plant health with biodynamic sprays (Demeter, n.a.): horn manure (made from cow manure buried inside a cow horn during the winter months) enhances the life of the soil, horn silica (prepared from ground quartz crystals buried in a cow horn over the summer months) increases plant immunity, strengthens photosynthesis, and enhances ripening, and horsetail tea helps prevent fungal diseases

and balances the watery element in plants and soil;
- Supporting integrity and diversity in seeds and breeds: favouring open-pollinated, heirloom, and non-GMO seeds and heritage breeds of animals, locally-adapted and resistant to pests and diseases;
- Treating animals with respect: supporting animals' health, never feeding them with animal by-products, raising calves, lambs, and kids on the milk of the herd, chickens keep their beaks and cows their horns, and all animals have access to the outdoors and to forage freely;
- Approaching pests and diseases holistically: incorporating a robust diversity of plants and animals, creating a habitat where natural predators, pests, and diseases have few places to thrive, trying to find ways to adjust any imbalances should they arise and using biological controls as a last resort;
- Cultivating awareness of nature: strengthening farmers' ability to work creatively with the dynamics of the land and the wider bioregion;
- Working in rhythm with the earth and cosmos: observing the rhythms and cycles of the earth and stars to understand their influence on the growth and development of plants and animals, using biodynamic calendars to support this understanding and provide detailed information and indications of optimal times for sowing, transplanting, cultivating, harvesting, and using biodynamic preparations;
- Upholding agricultural integrity with the biodynamic certification: the Demeter Biodynamic Standard for certification is managed worldwide, providing a global market for biodynamic products;
- Offering regenerative solutions for the future: forging the path for a conscious, participatory, and responsible way of farming, contributing to the ecological, economic, social, and spiritual vitality of a farm's surrounding community;
- Contributing to social and economic health: biodynamic farmers pioneered community-supported agriculture (CSA), and many practitioners work in creative partnerships with other farms, schools, restaurants, hotels, medical and wellness facilities, and the like.

Challenges and opportunities

Specific challenges for biodynamic agriculture, according to WUR (van Doorn et al., 2016), could be construed as the approach's unique strengths, in that it has a strong spiritual side, caters to a niche market, and requires its own training and quality mark. The fact that there is a long-standing certification for biodynamic farms and products helps provide the approach with a market. At the same time, its market niche is small, and it may well be that the esoteric, spiritual element differentiating this approach from others is what puts off many people who might otherwise be sympathetic. In terms of absolute numbers, 5000 Demeter-certified farms worldwide do not make for a critical mass. Indeed, in Europe the certification is not as widespread as EU organic (BDA Certification, n.a.), which in 2016 counted nearly 250,000 organic certified farms within the EU (DG AGRI, 2019). Many other labels have come onto the market since Demeter was first introduced, which may have contributed to a degree of competition between them. According to the Research Institute for Organic Agriculture (FiBL) (BDA Certification, n.a.), Demeter regulations were the most stringent, with Demeter standards allowing the fewest food additives in processed food as compared to other labels.

In terms of sustainability, the principles and practices of biodynamic agriculture clearly aim to address environmental and social objectives; it is based first and foremost on safeguarding ecological principles, while the social side of the approach has, for instance, helped to develop community-supported agriculture (*see* Chapter 4). The certification and the bringing together of practitioners has helped solidify the approach's presence on the market. With consumer demand for Demeter products growing in certain places (for instance, in the UK (BDA Certification, n.a.)), and the number of certifications increasing in others (e.g. the US (Chhabra, 2017)), the approach could be seen as continuing to hold promise. At the same time, as with other similar labels, biodynamic certifications should probably remain wary of how their brand performs and what place it holds in the eyes of the consumer, to help it survive label fatigue (Subramanian, 2019) in an expanding pool of certifications on the market.

3.5 Organic farming

Definition

Until roughly the 1920s, food was produced using traditional farming methods; it was only later that a new era of increased chemical and synthetic pesticide usage began (OrganicNet, 2016). The beginnings of organic agriculture may be traced as far back as 1840, to the development of mineral plant nutrition theory. However, the modern organic movement developed in parallel with industrialised agriculture (OrganicNet, 2016), with pioneers of this movement seeking to find alternative ways to address soil depletion, low food quality, and yields. **The modern organic movement sprouted in the early 20th century, primarily in Europe and later in the United States**. Following Rudolf Steiner's 1924 publication, which laid the foundation for biodynamic agriculture, and the founding of the Demeter label in 1928, it was Lord Northbourne who first used the term "organic farming" in 1939 (explained in detail in his book "Look to the Land", published in 1940). Today, *organic farming is a well-established approach, in terms of the market as well as supporting legislation*. The International Federation of Organic Agriculture Movements (IFOAM) was founded in 1972, and the Research Institute for Organic Agriculture (FiBL) in 1973. IFOAM's definition for organic farming outlines it as "*a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity, and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promotes fair relationships and a good quality of life for all involved.*" (IFOAM, 2005).

In 1991, the EU provided a legal framework (European Parliament and Council, 2018) for the designation of organic agriculture, and today EU regulations on organic farming are designed to provide a clear structure for the production of organic goods across the whole of the EU, thereby satisfying both consumer demand for trustworthy organic products and a fair marketplace for producers and distributors. Within this framework, guidelines and regulations exist for **various types of production, and may be applied in various geographical contexts**.

In the EU, all **food producers, processors or traders who wish to market their food under the organic label have to register with a control agency** or body which is responsible for verifying that the operator acts in compliance with organic rules (European Commission, n.a.). According to IFOAM (n.a.), for farmers wanting to demonstrate the organic quality of their production to their buyers, there are several options for certification in compliance with a particular standard:

- Individual Third Party Certification (TPC), carried out by an independent body;
- Group Certification based on Internal Control System (ICS), where several farmers can be certified collectively by a TPC body, which assesses the performance of this system;
- Participatory Guarantee System (PGS), or participatory certification, which certifies producers based on active participation of producers and consumers in the guarantee process.

Principles

According to the European Commission (EC) (n.a.), organic farming is an agricultural method that aims to produce food using natural substances and processes. As such, it tends to have a limited environmental impact due to the fact that it encourages:

- The responsible use of energy and natural resources;
- The maintenance of biodiversity;
- Preservation of regional ecological balances;
- Enhancement of soil fertility;
- Maintenance of water quality.

Organic farming also encourages a high standard of animal welfare and requires farmers to meet the specific behavioural needs of animals.

IFOAM, the international umbrella organisation for the organic sector, proposes four principles for organic agriculture, namely:

- The principle of health, whereby "Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible."

- The principle of ecology, whereby "Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them."

- The principle of fairness, whereby "Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities."

The principle of care, whereby "Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment" (IFOAM, n.a.).

Practices

The EU has a set of rules for organic production, which govern all areas of organic production and are based on a number of key principles (European Commission, n.a.), laid out in the regulation which governs organic farming (European Parliament and Council, 2018), including:

- Prohibition of the use of GMOs;
- Forbidding the use of ionising radiation;
- Limiting the use of artificial fertilisers, herbicides and pesticides to the minimum;
- Prohibiting the use of hormones and restricting the use of antibiotics (only when strictly necessary) for animal health.

This means that organic producers need to adopt specific approaches to maintaining soil fertility and animal and plant health including:

- Crop rotation;
- Cultivation of nitrogen fixing plants and other green manure crops to restore the fertility of the soil;
- No use of mineral nitrogen fertilisers;
- To reduce the impact of weeds and pests, organic farmers choose resistant varieties and breeds and use techniques encouraging natural pest control;

- Encourage the natural immunological defence of animals;
- In order to maintain animal health, organic producers need to prevent overstocking.

In the EU, specific rules (European Commission, n.a.) exist for various sectors and areas, including for livestock, the food chain, permitted substances in organic production, rules or wine, aquaculture, hydroponics, and organic seed databases. For instance, EU rules do not allow for plants grown hydroponically to be marketed as organic, because certified organic production is only possible when plants are grown naturally in soil.

According to IFOAM (2017, in FAO, 2019), characteristics of organic agriculture include:

- Maximised use of natural alternatives to synthetic inputs (pesticides, fertilisers, veterinary products, etc.);
- A focus on soil health (use of compost, minimal tillage, cover crops, green manure, etc.);
- Diversification of species, breeds or varieties (polyculture, rotations, companion crops, animal–plant integration, etc.);
- Maintenance or establishment of semi-natural habitats (grass strips, flower strips, hedges, etc.);
- Livestock management that privileges animal welfare (cage-free management, access to open fields, etc.), sustainable pasture management and use of local feed sources.

Challenges and opportunities

Specific challenges relating to organic farming are often linked to evaluating its feasibility, often because many changes may only be observable in the long term, and success in organic agriculture depends greatly on local conditions. For instance, areas with an abundance of organic material and labour may better be able to utilise compost as a means to maintain soil fertility (FAO, 1998). Factors related to transitioning to organic agriculture from conventional agriculture include implications for labour and other inputs (e.g. water, nutrients, energy, knowledge, and animal breeds), as well as crop rotation, yield, and total farm production (FAO, 1998). While regulations and labelling behind this approach have created a strong market for organic products, and indeed organic farming is the only legally defined approach for sustainable agriculture, its prescriptive nature also means prospective practitioners are faced with a barrier to entry. While some of the strict requirements may indeed better serve the objective of environmental protection, the challenges to adopting the approach for farmers become higher still when a proliferation of labels and standards add additional requirements to the EU baseline (e.g. Soil Association, Bioland, Naturland, KRAV, etc.).

In terms of sustainability, organic farming seeks to minimise the use of synthetic and chemical inputs, and from an environmental perspective, this is positive, although the EU regulation includes no specific rules to preserve water resources nor rules against the conversion of natural habitats, and “intensive organic” has been criticised as contributing to nitrate leaching (Dahan et al., 2014). However, not all dimensions of sustainability are necessarily compatible with organic practices (FAO, 1998). For instance, while organic farming might work well at a smaller scale, it can also be argued that it uses more arable land and water to achieve the same yield as conventional agricultural practices, which raises questions about its feasibility and impact on land use should it be more widely deployed (Miller, 2017; Dahan et al., 2014; Savage, 2015). Currently, the organic price premium seeks to increase farmer profitability, and this (together with the savings on synthetic pesticides and fertilisers) may outweigh the additional costs associated with organic production. However, it may be also questioned whether the high returns could be maintained in the event that organic farming becomes more mainstream. At present, the organic certification and market are strong, with clear legal standards and huge brand recognition behind it. In addition to a steady increase in the area under organic production, total retail sales for organic within the EU increased by nearly 11% between 2016 and 2017 (Willer & Lernoud, 2019). Although organic rules are clearly defined, actual standards and control may vary considerably between organic certifiers and organic producers, which could risk undermining the long-term credibility of organic farming. In response to the rapid expansion of the market, and in order to strengthen the legal framework for the industry, the new EU organic legislation, to be implemented from 2021, aims to guarantee fair competition for organic farmers while preventing fraud and maintaining consumer trust (European Commission, n.a.). In recent years, IFOAM has been talking about the transition (IFOAM, n.a.) to organic agriculture in terms of phases, i.e. Organic 1.0 (pioneering organic agriculture), and Organic 2.0 (the codification organic practices, which in Europe brought about the creation of EU-wide rules on organic). The goal now is Organic 3.0, wherein organic is brought out of its niche and mainstreamed to contribute to sustainable development.

3.6 Conservation agriculture

Definition

Conservation agriculture is an approach **developed in Brazil and Argentina in the 1970s** (Project Drawdown, n.a.), as a response to the "Dust Bowl" period in the USA, which had resulted in severe soil erosion (EIP-AGRI, 2015a).

Centred on soil, and stemming from the Latin root of "conserve" meaning "to keep together", *conservation agriculture aims to "keep the soil together" as a living ecosystem that enables food production and helps address climate change* (Project Drawdown, n.a.). Through the conservation of soil, the approach contributes to enhancing biodiversity both within and above the soil, capturing more carbon, enabling a higher efficiency of water and nutrient use, and ultimately resulting in improved and sustained food production (FAO, n.a.). Conservation agriculture is an approach that **can be implemented on any geographical terrain, on farmland used for the cultivation of crops** (Kassam et al., 2018). It is a widely adapted approach, extending from the equatorial tropics to the Arctic Circle, from soils that are 90% sand to soils that are 80% clay (Kassam et al., 2018).

Principles

Three core principles underpin conservation agriculture, namely:

1. Minimising soil disturbance;
2. Maintaining soil cover, and;
3. Managing crop rotation (FAO, 2014).

Practices

The key practices implemented under conservation agriculture relate back to the three core principles, like so:

1. Minimising soil disturbance, which entails reduced or no tillage (through direct seed and/or fertiliser placement);

2. Maintaining soil cover by growing cover crops, leaving crop residues on land post-harvest, and mulching;
3. Managing crop rotation, incorporating a wider range of plant species.

Challenges and opportunities

Specific challenges relating to the implementation of conservation agriculture are its dependence on herbicides, primarily to avoid soil disturbance when preparing to sow, and the consequent reliance on herbicide-resistant crops (Eslami, 2014; Lee & Thierfelder, 2017)· and specific machinery adapted for direct seeding. These techniques reduce the higher levels of labour otherwise required to apply conservation agriculture principles, but they also challenge some of the desired effects of the approach. Practically speaking, the short-term effects of switching to no tillage can present difficulties in de-compacting the normally ploughed layer of soil, with compacted soil resulting in lower water infiltration and soil water content, in turn leading to waterlogging and hindered plant and root growth. At the same time, the rule on soil disturbance does not seem overly strict as the use of subsoilers is permitted (Corsi & Muminjanov, 2019). The weight of the machinery used to plough the soil under in conventional agriculture has been argued as one of the main contributors to soil compaction in the first place. This would signal that conservation agriculture should be less soil-compacting overall. Soil compaction can be further counteracted by maintaining soil cover (the second principle) – and indeed all three principles must be observed together (Kassam et al., 2018) to fully realise the goals of the approach. In the longer term, following the implementation of conservation agriculture mechanisms, soil organic matter (SOM) and soil aggregates will improve, which will naturally result in less compacted and degraded soil.

In terms of sustainability, the environmental benefits of conservation agriculture, in taking care of the soil on which life depends, are clear. At the same time, this "narrow" focus on soil conservation, although it might claim indirect benefits, does not directly deal with other environmental aspects, such as water, biodiversity, or pest resistance to chemical use. Conservation agriculture could, in fact, lead to adverse impacts on the environment through its over-reliance on herbicides and genetically modified herbicide-resistant crops (Eslami, 2014). From an economic standpoint, in some cases the implementation of the approach may result in the demand for labour to increase, however the costs for certain machinery, fuel and fertiliser will at the same time decrease. For other cases, such as those observed in Africa, the decreased demand for labour for land preparation at the beginning of the growing season can make for significant (labour and time cost) savings (FAO, 2001). The approach is implemented around the world, however over 87% of all the land on which conservation agriculture is utilised may be found in five countries; the United States, Brazil, Argentina, Australia, and Canada (EIP-AGRI, 2015a). In Europe, adoption is below 2% of all arable land (EIP-AGRI, 2015a), although some sources claim it to be up to 25% of all arable land (Kertész & Madarász, 2014).

3.7 Regenerative agriculture

Definition

Coined by Robert Rodale in the early 1980s (Gold & Potter Gates, 2007), regenerative agriculture builds on conservation agriculture in that it seeks to enhance and sustain the health of soil by restoring its organic matter, boosting its fertility and productivity. Its primary focus is on soil health, with the underlying theory that "*the world cannot be fed unless the soil is fed*" (Project Drawdown, n.a.). Through improving soil health, regenerative agriculture aims to increase agricultural yields and resilience in the face of climate instability (Rodale Institute, n.a.).

According to the Food and Land Use Coalition (FOLU), regenerative agriculture is considered to be one of the ten critical transitions needed to transform food and land use (FOLU, 2019). Their definition for the approach considers it to consist of *practices that regenerate soil, reducing but not necessarily eliminating synthetic pesticides and fertilisers, and going beyond the reduction of negative effects towards ensuring that agriculture has a positive effect on the environment*. At the same time, it seeks to maintain high levels of productivity. Like conservation agriculture, regenerative agriculture **can be implemented on any geographical terrain, while extending its focus to consider livestock practices in addition to the cultivation of crops** (FOLU, 2019; Regeneration International, n.a.). Stemming from the United States, there is less evidence of uptake of the approach in Europe. However, recent initiatives in Europe have connected the approach to permaculture (Start Regenerative Agriculture, 2018) and organic farming (IFOAM, n.a.). Meanwhile in the US, the Rodale Institute has further developed an approach to "regenerative organic agriculture".

Principles

According to a paper by California State University and The Carbon Underground (2017), regenerative agricultural practices aim to:

1. Contribute to generating/building soils, soil fertility, and health;
2. Increase water percolation, water retention, and clean and safe water runoff;
3. Increase biodiversity and ecosystem health and resilience; and
4. In a shift from being a source to being a sink for carbon, invert the GHG emissions associated with conventional agriculture through carbon sequestration.

Systemic and Soil Capital (2020) outlines a similar five principles underpinning regenerative agriculture, namely to:

- Minimise or eliminate agrochemicals;
- Maintain permanent cover of the soil, ideally with living roots;
- Minimise soil disturbance;
- Maximise functional biodiversity; and
- Adapt to context-specific design.

Practices

Regenerative agricultural practices include (California State University & The Carbon Underground, 2017; Project Drawdown, n.a.; Regeneration International, n.a.):

1. No-till / minimum tillage to enhance soil aggregation, water infiltration and retention, and carbon sequestration;
2. Boosting soil fertility biologically by closing nutrient loops through the application of cover crops, crop rotations, perennial crops, compost, and animal manure - minimal or no use of synthetic fertilisers and pesticides, and no external nutrients (in-farm fertility);
3. Building biological ecosystem diversity through composting, intercropping, multi-species cover crops, agroforestry, silvopasture, and borders planted for bee habitat and other beneficial insects;
4. Well-managed grazing practices (e.g. rotational grazing, pasture cropping) to stimulate plant growth, increased soil carbon deposits, pasture and grazing land productivity, soil fertility, insect and plant biodiversity, and soil carbon sequestration.

Challenges and opportunities

Specific challenges for regenerative agriculture are similar to those for conservation agriculture, as previously described. For the cultivation of crops, in the short-term no or minimal tillage may lead to difficulties de-compacting the plough layer of soil, lower water infiltration and hindered plant and root growth. However, in the longer term, and by maintaining soil cover, these impacts can be overcome, and yields achieved with lower external inputs. While the approach may in some cases be more labour-intensive, the need and costs for external inputs such as synthetic fertilisers and pesticides will be reduced. While the exact workings of soil microbe systems and the most effective ways to sequester carbon have yet to be determined (Temple, 2019), an important way in which no or minimal tillage systems offset emissions (also relevant for conservation agriculture) is through the reduction of energy used for soil inversion through ploughing or heavy cultivations. This reduces the fuel burned by farming equipment to conduct regular operations, as well as the oxidation of soil when it is broken up and exposed to the air.

In terms of sustainability, regenerative agriculture aims primarily to secure environmental benefits, albeit through a narrower focus on soil health. Its scope is somewhat broader than conservation agriculture, in that it considers not only crops but also livestock farming, and involves the mixing of crops and livestock, to further boost soil quality and on-farm fertility. Through improving soil health, including its fertility, structure, and possibility for plants to grow deeper roots, it aims to increase agricultural yields and resilience to climate instability, thus potentially presenting economic benefits to implementing this approach. In terms of its application, most sources and examples of implementation of the approach stem from the United States, however the approach is gaining recognition and interest in Europe, with initiatives from Finland to Belgium (Systemic Soil Capital, 2020) to Spain (Regeneration Academy, 2018). As outlined by the FOLU (2019), regenerative agriculture aims to go beyond reducing the negative effects of agriculture towards ensuring it has a positive effect on the environment. While this is an ambitious aim, it is also one that is difficult to measure. It may be worth noting that, while a focus on soil health can have numerous positive side effects, the approach does not explicitly consider a number of important environmental issues, such as providing landscape elements and wildlife habitats.

3.8 Carbon farming

Definition

With similar origins to conservation and regenerative agriculture, carbon farming has been gaining traction in recent years, as an approach in its own right, taking on a variety of ways of implementation across different geographical terrains and production systems. Examples of carbon farming in practice can be found around the world, such as the Carbon Farming Network in California which supports training and workshops on carbon farming and healthy soils (Carbon Cycle Institute, n.a.) an EU initiative on carbon farming in the North Sea Region (Interreg, n.a.), to perhaps more environmentally-contested examples linked to carbon cap and trade schemes, allowing farmers sequestering carbon to sell their carbon credits to heavy polluters (e.g. in California and, notably, in Australia) (Barth, 2016). The “4 per 1000” initiative launched by France at the COP 21 in Paris (4 per 1000, 2015), could also be linked with this approach. Today, in the growing urgency to act on climate change and in order to meet its ambition to become climate-neutral by 2050, the EU is keen on scaling up the approach (Gillman, 2019; Nijman, 2019; Ecologic, 2019).

Based largely on the principles of conservation and regenerative agriculture, carbon farming "*involves implementing practices that are known to improve the rate at which CO2 is removed from the atmosphere and converted to plant material and/or soil organic matte*" (Carbon Cycle Institute, n.a.). Its key goal is to store carbon beneficially in soils as well as vegetation, stemming from a sense of opportunity and responsibility with respect to the agricultural sector's role in climate change. This reflects how, on the one hand, unsustainable land management is among the largest contributors to climate change, while on the other, a land-based sector like agriculture holds enormous potential to sequester CO2 and reduce GHG emissions (Carbon Cycle Institute, n.a.) (with actions such planting or restoring forests, peatlands, and wetlands other key land management techniques in this respect).

Principles

The key principles underpinning carbon farming consist of:

1. GHG emissions reduction; and
2. carbon sequestration.

Implementing carbon farming can also help address other environmental impacts related to agriculture, including groundwater and surface water degradation, although this is not the focus of the approach. Resource efficiency is another component, albeit with the objective of reducing emissions – converting manure and other waste into compost is resource-efficient, but it avoids the release of GHGs, particularly methane (Carbon Cycle Institute, n.a.).

Practices

According to the Carbon Cycle Institute (n.a.), carbon farming practices may include:

- Residue and tillage management such as no-till, strip-till, and direct seed;
- Multi-story cropping, alley cropping;
- Forage and biomass planting, range planting, planting herbaceous covers;
- Mulching/compost application;
- Nutrient management;
- Establishing windbreaks/shelterbelts, contour buffer strips, vegetative barriers, forest buffers, filter strips, hedgerows, grassed waterways, wetland restoration;
- Tree/shrub establishment; and
- Practicing silvopasture.

Challenges and opportunities

Specific challenges relating to carbon farming are much the same as those for conservation and regenerative agriculture, as indeed the approaches are very similar. Carbon farming, however, in addition to sequestration, also aims to include mitigation efforts. Much like climate-smart agriculture (see following section), carbon farming comes with a large variety of potential practices that may be implemented, so long as they meet the objectives of carbon sequestration or emissions mitigation. It may be difficult to find exactly the right fit for a certain farm (in terms of its geographical and production specificities), that would yield the expected results. Moreover, there are difficulties measuring the impact of farming practices in terms of carbon sequestration and emissions reduction, as the evidence based on field data is still quite rudimentary. Coupled with the lag between the practices being implemented on the ground and them being eventually reflected (if accepted) in national inventories (i.e. IPCC greenhouse gas accounting), this can be discouraging for practitioners.

In terms of sustainability, this approach (like regenerative agriculture and other soil or climate-focused approaches) is gaining momentum, with a number of farmers exploring its potential, as well as governments mainstreaming the term. At the same time, uncertainty remains concerning how much of a climate benefit the approach provides: there are still many unknowns regarding the workings of soil microbe systems, including what would be the most effective practices to store CO2 (Temple, 2019), with some studies claiming limited potential of no-tillage systems for climate change mitigation (Powlson et al., 2014). Others call the approach, with its focus on active farmland's potential to mitigate climate change, a diversion from more important priorities for minimising the climate impact of agriculture, namely to stop clearing land for it, and to rather convert some fields back to forests, grasslands, and peatlands, which are crucial carbon sinks (Temple, 2019) (with the understanding that land clearing is an issue of varying scales and significance depending on the country). In terms of environmental sustainability, successful transformation and the extent of carbon stored and soils replenished will also depend on the specificities of the terrain and the production system (Velasquez-Manoff, 2018). Like the conservation and regenerative approaches, carbon farming includes a lower focus on key environmental challenges beyond climate change, such as biodiversity. In terms of social and economic sustainability, in the long-term healthy soils will benefit communities and production, though, in the short term, measures such as financial incentives would probably be needed. It is, however, an open question whether it would be better to support the achievement of the results e.g. in terms of carbon sequestered (noting that linking agriculture to carbon markets is often seen as controversial), or to support the actual practices implemented, for which the direct benefits might be difficult to measure (Johnson, 2019). The fact that decades of soil carbon storage can be reversed very quickly when reverting to old methods such as ploughing, suggests that improved carbon storage could be more effectively achieved through basic rules such as mandatory buffers or protection of trees, rather than through carbon credits or payments. In the context of carbon farming, the EU has recently commissioned a study about the effectiveness and implementation of the approach, and is consulting with stakeholders on the ways forward regarding monitoring, reporting, verification, rewards mechanisms, and solutions to ensure the integrity of results-based farming schemes (Ecologic, 2019).

3.9 Climate-smart agriculture

Definition

Launched by the FAO in 2010 at The Hague Conference on Agriculture, Food Security, and Climate Change (FAO, n.a.)**,** climate-smart agriculture was developed in the context of food security and development goals in the face of the growing threat of climate change. The strong focus on food security was tied at the beginning to climate mitigation and, as it evolved, to climate adaptation. A highly political and strategic concept from its inception, it also endeavours to be a holistic concept, aiming to address and develop the technical, policy, and investment conditions necessary to achieve sustainable agriculture for food security under climate change (Verhagen et al., 2017).

The FAO, World Bank, IFAD, UNEP, WFP, and CGIAR are all promotors of the approach, which has been accepted or adopted as such relatively quickly following its first introduction (Verhagen et al., 2017), with the EU also supporting climate-smart agriculture and forestry projects (European Commission, 2017). The Global Alliance on Climate Smart Agriculture (GACSA) was launched during the UN Climate Summit in September 2014 in New York. According to the FAO (n.a.), climate-smart agriculture "*aims to enhance the capacity of the agricultural systems to support food security, incorporating the need for adaptation and the potential for mitigation into sustainable agriculture development strategies.*" It proposes integrated approaches to tackle challenges of food security, development, and climate change, while recognising that the implementation of options by specific countries will be shaped by their contexts and capacities – the concept of climate-smart agriculture is thus "*evolving and there is no one-size-fits-all blueprint*". Climate-smart agriculture may be implemented for **any type of production and within any geographical scope**, where it can be tailored in terms of practices applicable to the specific context.

Principles

Centred on climate change, climate-smart agriculture is based on the three principles - or triple objectives - of:

1. Increasing food security through an increase in agricultural productivity and incomes;
2. Enhanced resilience and adaptation to climate change;
3. Reduced GHG emissions and/or carbon sequestration (i.e. climate mitigation) (Verhagen et al., 2017; FAO, n.a.).

According to the FAO (n.a.), this does not imply that every practice applied following the climate-smart approach, in every location, should produce "triple wins". Rather, the approach takes the three objectives into consideration to inform decisions from the local to global scales and over the short and long term, reducing trade-offs and promoting synergies to obtain solutions adapted to the specific context.

Practices

As stated by the FAO (2010; n.a.), climate-smart agriculture does not propose a set of practices that can be universally applied, but in its holistic nature is, rather, an approach involving different elements embedded in a local context. It relates to actions both on-farm and, notably, beyond the farm; incorporating technologies, policies, institutions and investment.

Practices may consider (FAO, n.a.):

- The management of farms, livestock, crops, and aquaculture in a way that balances the needs for food security and livelihoods with climate adaptation and mitigation;
- Ecosystem and landscape management to conserve ecosystem services, important for food security, adaptation, and mitigation;
- Services for farmers and landscape managers to better be able to manage climate risks, impacts, and mitigation measures;
- Changes in the wider agri-food system, including demand-side measures and value chain interventions.

Practices, as listed by the FAO (n.a.), can include:

- Integrated practices: i.e. the management of production systems and natural resources covering an area large enough to produce vital ecosystem services but small enough to be managed by the people using the land;

this includes integrated crop and livestock production systems and agroforestry.

- Crop production: adapting crop production to climate change, including crop varietal selection, plant breeding, cropping patterns and ecosystem management approaches; using crop production for mitigation, e.g. reducing the use of inorganic fertilisers, avoiding soil compaction or flooding to reduce methane emissions (e.g. in paddy rice systems) and sequestering carbon (e.g. planting perennial crops and grass species); as well as conservation agriculture, systems of rice intensification (SRI), and alternate wetting and drying (AWD).
- Livestock measures: reducing GHGs through pasture management, zero-grazing, grassland restoration and management (e.g. silvopastoral systems), manure management (e.g. recycling and biodigestion) and crop-livestock integration.
- Forestry measures: sustainable forest management (SFM).
- Urban and peri-urban agriculture: hydroponics, trees outside the forest (TOF).
- Genetic resources and biodiversity: measures to improve the diversity of species, the diversity within species, and the diversity of ecosystems.
- Land and water management: sustainable land and water management (SLM), including the restoration of peatlands and degraded lands, managing grasslands, range lands, and forest crops, water and irrigation management, increasing the amount of carbon sequestered in the soil, and enhancing the level of nutrients in and water retention of soil.
- Proactive drought management: including effective monitoring and early warning systems to deliver information to decision makers and for impact assessments, pro-active risk management measures, and preparedness plans that incorporate emergency response programmes.
- Energy: including increased energy efficiency of farming practices, as well as minimising the use of non-renewable energy sources; integrating food and energy production, creating synergies between energy-smart and climate-smart agricultural practices via resource-efficient farming practices that reduce pressures on land, reduce GHGs, and lessen the reliance on fossil fuels.
- Food loss and waste: investments into food waste reduction as a means to achieving economic, environmental, and social dividends, contributing to food security, and reducing GHGs.
- Nuclear techniques: applying nuclear and isotopic techniques to support climate-smart agriculture (FAO and IAEA, n.a.).

Challenges and opportunities

Specific challenges relating to climate-smart agriculture are two-fold. Firstly, the very holistic nature of climate-smart agriculture poses its own limitations, lacking focus by attempting to cover many different types of actions, spatial scales, and domains. Secondly, the approach has received criticism from civil society for justifying nearly any form of agriculture, and in doing so allowing for business to continue as usual (FCRN Foodsource, n.a.). According to WUR (Verhagen et al., 2017), more than 100 civil society organisations had rejected GASCA upon its establishment in 2014 on the grounds that the "climate-smart agriculture paradigm provides a platform for agribusiness and industrial agriculture to promote their practices as solutions to climate change". A letter by Action Aid (2017) further outlines a growing concern that pressure to adopt climate-smart agriculture (supported primarily by a number of industrialised countries) will translate into developing countries' food systems taking on an unfair mitigation burden. Further to this, Action Aid also notes the variety of initiatives branding themselves as climate-smart agriculture, pointing out some positive initiatives that incorporate beneficial agroecological farming practices, while others effectively fail to address the approach's principles.

In terms of sustainability, the "triple wins" of the climate-smart approach endeavour to address environmental, economic, and by extension social sustainability. However, there are no set climate, environmental or social criteria underpinning the approach (Action Aid, 2017). In practice, what may be called climate-smart agriculture may not be delivering what its very principles aim to achieve. Furthermore, while following just one of the principles (e.g. increasing productivity) cannot be a climate-smart approach, seeking to increase productivity while at the same time reducing emissions, for example, can prove to be challenging. It should be noted that it is not necessarily every country's desire to increase productivity; climate-smart agriculture could also make already highly productive agriculture more resilient without further increasing its productivity. Finally, for the success and sustainability of any agricultural approach, it is vital to include various stakeholders and sectors along the food value chain. From this perspective, the fact that the approach has gained crucial support, and the needed involvement from both the private and public sectors can, from the outset, be seen as a positive element of climate-smart agriculture.

3.10 High nature value farming

Definition

According to the European Forum on Nature Conservation and Pastoralism (High Nature Value Farming, n.a.), high nature value farming (or HNV farming) is an approach to agriculture that **emerged as an intellectual construct in Europe in the early 1990s**. It is based on the recognition that biodiversity in Europe is dependent on and intertwined with traditional, low-intensity farming systems across large areas of countryside, and tries to describe and capture a host of traditional farming practices and systems that have existed in Europe (and elsewhere) for centuries, especially for the purposes of policymaking. The approach considers many landscapes and habitats of significance for biodiversity across Europe to have been created over centuries through traditional farming practices, such as extensive grazing, including pastoralism, and low-input, small-scale cropping. The term HNV farming was coined to emphasise the crucial role of low-intensity farming for European biodiversity conservation (Baldock et al., 1993 in Oppermann et al., 2012), and claims that biodiversity conservation goals in Europe cannot be met solely by protecting particular species and habitats or designating certain areas for management. Proponents of the approach in the EU have been asking for a fundamental shift in the distribution of CAP funds away from more intensive farming, in order to support these low-intensity land uses that may still be found in many rural areas but are at risk of disappearing (Oppermann et al., 2012).

The EC considers HNV farming as an agri-environmental indicator to monitor the integration of environmental concerns into the CAP. It is understood as "the causality between certain types of farming activity and corresponding environmental outcomes, including high levels of biodiversity and the presence of environmentally valuable habitats and species" (Eurostat, n.a.). It is thus a key indicator for the assessment of the impact of policy on biodiversity, habitats, and ecosystems dependent on agriculture and traditional rural landscapes; the main indicator is the share of estimated HNV farmland in a given utilised agricultural area (Eurostat, n.a.). The landscapes in question, classified by the approach as high nature value farmland (or HNV farmland), are **present across all of Europe and cover a broad range of types of agricultural production**. However, this is mostly semi-natural pastures and some cropland that does not lend itself to, or has not seen the economic means and opportunity to begin practicing intensive agriculture.

Principles

The principles of HNV farming centre on the preservation and maintenance of traditional farming systems, which in turn act to preserve and maintain traditional landscapes and biodiversity. These traditional farming systems practice low-intensity agricultural production, wherein HNV farming is founded on the recognition that biodiversity is greater on farmland that is managed at a low intensity, in terms of machinery, fertilisers, pesticides, and livestock. In particular, according to Oppermann et al. (2012), the HNV farming approach stipulates that, being at the lowest end of the farming intensity spectrum, not only the farmland margins but also the productive land itself supports a range of wildlife species absent from intensively farmed land.

HNV farmland may be classified in three types: farmland with a high proportion of semi-natural vegetation (Type 1), farmland with a mosaic of low-intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers, etc. (Type 2), and farmland supporting rare species or a high proportion of their European or world population (Type 3).

Oppermann et al. (2012) highlight the societal value created by HNV farming and HNV farmland, including the creation of public goods, which include ecosystem services, water, soil, and climate protection, quality of food, cultural identity, and aesthetics. Genetic diversity, which provides a unique value to the landscape, is also highlighted. HNV may also be used as an indicator, for the many functions and services of the agricultural landscape.

Practices

According to Oppermann et al. (2012):

Grassland-use types under HNV farming include:

- Hay meadow with a single annual cut;
- Hay meadow with two annual cuts;
- Litter meadows;
- Water meadows;
- Leys and silage production (with a limited number of cuts per year);
- Semi-open pastures and wooded pastureland;
- Continuous grazing;
- Ration grazing, rotational grazing, cell grazing, paddock grazing.

Conservation methods, to maintain and preserve HNV landscapes, include:

- Organic farming (through the omission of chemical applications);
- Nature conservation set-asides;
- Large-scale fallow areas;
- Planned blooming strips;
- Mixed crops of cereal and wild herbs and weeds.

There are also HNV permanent low-intensity cropping systems for olives, oaks, vines, fruit trees, and nut trees.

Challenges and opportunities

Specific challenges for HNV farming stem largely from the fact that many traditional farming systems have been replaced by more intensive and industrial forms of farming, particularly on more productive land. Nowadays, HNV farms may be found nearly exclusively in the most marginalised agricultural land in Europe, such as mountainous regions, which are on the one hand less touched by human development, and on the other better suited to lower-input production due to the physical constraints. As a result, HNV farmers often operate under difficult socio-economic conditions.

In terms of sustainability, with its low or limited intensification potential, the economic and social sustainability of HNV farming faces growing threats. While this is the reality for many farmers, certain traditional products see a steady, high demand, and thus some types of HNV farming can be quite successful – e.g. the case for Iberian ham produced in the Spanish dehesa. This is further supplemented by support through the CAP which, for types of HNV farming that may not have a strong market, becomes crucial. The CAP links its support for HNV farming to biodiversity, and it is indeed the approach's biodiversity-related benefits that are its primary asset; the very basis of HNV farming rests on the aim to preserve and maintain traditional landscapes and biodiversity. While supporting any kind of biodiversity is indeed positive, it should be noted that not all species might thrive on HNV landscapes, as wildlife that had historically been pushed back by HNV farming could continue to be marginalised.

3.11 Low external input agriculture

Definition

Low external input agriculture (LEIA) **developed as a concept in the 1980s**, gaining ground with the establishment of the Information Centre for Low External Input and Sustainable Agriculture (ILEIA) in 1984 (Kessler & Moolhuijzen, 1994). ILEIA was founded, and LEIA developed, as a response to the criticisms surrounding Green Revolution technology being neither sustainable nor feasible for many small-scale farmers around the world (ILEIA, n.a.). The concept aimed to redesign the agricultural system by optimising the use of biological resources, keeping changes to the natural ecosystem as well as the use of external inputs at a minimum (Pimentel et al., 1989 in Kessler & Moolhuijzen, 1994).

Today, LEIA is described as *an approach referring to a set of agronomic practices that aim to reduce the use of inputs from outside the production system*. These inputs may include water, energy, seeds, chemicals, and the like. According to the FAO (2019), LEIA does not mean the elimination so much as a reduction of external inputs, such as pesticides and fertilisers, placing a greater emphasis on improved agronomic practices, integrated pest management, labour and overall farm management, towards maintaining yields. LEIA is an approach that can be applied to **various production systems in various geographical contexts**. Other terms sharing the same concept as LEIA include low external input sustainable agriculture (LEISA) (Kessler & Moolhuijzen, 1994) and low input farming systems (LIFS) (Solagro JRC, 2007).

Principles

Generally, low external input agriculture follows two principles (Gold, 2007; Biocyclopedia, n.a.), namely:

1. Minimising the use of external inputs into the farm system (off-farm resources) by using them in a complementary way;

2. Optimising the management and use of internal production inputs (on-farm resources) and locally available resources by maximising the complementary and synergistic effects of different components of the production system.

These principles mean ensuring a balanced and efficient use of nutrients, organic matter, water resources, genetic resources, and energy resources.

LEIA was developed at its outset with the aim of not only improving ecological sustainability but, simultaneously, also farmers' socio-economic conditions through the reduced use of, and dependence on, external inputs (Kessler & Moolhuijzen, 1994). Thus, further economic and social principles (Gold, 2007) of LEIA include:

- Sustained farmer livelihood systems;
- Competitiveness;
- Low relative value of external inputs;
- Equitable adoption potential (especially among small farmers);
- Reduced dependency on external institutions;
- Enhanced food security at the family and local level;
- Contribution to employment generation.

Practices

Key LEIA practices include:

- The use of green and animal manures, replacing fertilisers;
- Limiting herbicide, fungicide, and insecticide use so as to increase the potential for biological control;
- Crop rotation, intercropping, and cover cropping to manage pests, diseases, and weeds;
- Crop diversification to support soil structure, nutrient cycling, and nitrogen fixation.

Challenges and opportunities

Specific challenges for LEIA, according to FAO (2019), may stem from the fact that – similar to other approaches - this approach is more labour-intensive and provides less output than high external input alternatives. At the same time, low inputs mean lower expenditure and therefore there may well be overall benefits in terms of farm profitability. For those converting their farm to LEIA, this would require an initial investment into the required redesign of the agroecosystem, involving additional crops for diversification, additional labour, and necessary training. A period of decreased production follows the introduction of most LEIA techniques (FAO, 2019). More specific to this approach, defining what constitutes "low input" remains difficult, making LEIA a rather ambiguous concept (Gold, 2007).

In terms of sustainability, low external input agriculture is based on principles which are environmental, though not necessarily focused on biodiversity, as well as socio-economic, albeit more loosely formulated. The approach has a strong historical focus on empowering smallholders and local communities, which is promising and necessary for sustainability. Certain studies, however, have shown that success is often location-dependent (Kessler & Moolhuijzen, 1994). Sites rich in natural resources will do well without external inputs, while those which are not may risk further depleting their reserves. While closing the loop in a system with abundant, quality resources can provide significant returns, given the increasingly negative state of soil, water, biodiversity and ecosystem services around the world, it might be worth questioning whether an additional focus on rehabilitation and restoration might also be necessary.

3.12 Circular agriculture

Definition

While high on the political agenda today (European Commission, 2020), the concept of a circular economy is not a recent phenomenon. It was not until the 1960s, however, that the need to shift to closed-loop systems began to include environmental considerations at its core. In 1966 US economist Kenneth Boulding called for "a shift away from the expansionist "cowboy economy" where endless frontiers imply no limits on resource consumption or waste disposal, to "a spaceship economy" where everything is engineered to be constantly recycled" (Circular Academy, n.a.). Building on this, and on the concept of low external input agriculture**, the grounds for circular agriculture were laid out by Dutch researcher Jaap van Bruchem in the late 1990s**, when he discovered the importance of closing the loop in dairy farming (van der Hoeven, 2019). Conscious of the fact that there is too much nitrogen deposited on farmland as a result of the intensive use of fertiliser and imported feed concentrate, van Bruchem began feeding his cattle with high-fibre, low-protein feed, thus allowing them to produce better quality manure (low in ammonia). This manure was then used to produce more active soil, improve the microbiome, suppress denitrifying bacteria, and support healthy plants.

In recent years, WUR has further developed the concept of circular agriculture, based upon the premise that moving towards a circular food system implies minimising the input of finite resources, encouraging the use of regenerative ones, preventing system leakage of natural resources such as carbon, nitrogen, phosphorus, etc., and stimulating the reuse and recycling of unavoidable losses in ways that add the highest possible value to the food system (Jurgilevich et al, 2016, in de Boer & van Ittersum, 2018). In terms of farming, circular agriculture therefore takes a whole system approach, involving the integration of crops and livestock and making the best possible use of resources, including side streams (de Boer & van Ittersum, 2018), indicating a shift from production-efficiency to resource-efficiency. The approach can be applied in **various terrains and production systems**.

Principles

According to WUR (de Boer & van Ittersum, 2018), ensuring the best possible use of resources in the food system introduces a hierarchy to the principles underpinning circular agriculture. The baseline implication stipulates that arable land should be used primarily to produce plant biomass for human consumption. This means that preventing human-edible by-products takes first priority, while unavoidable human-edible by-products should be used as human food wherever possible. Only then may the residual by-products be recycled back into the food system in other ways, together with the by-products inedible for humans. This second priority action serves to enrich the soil, fertilise crops, feed livestock, or be transformed into bioenergy or other biomaterials, in that order (within this second priority action the highest priority is the soil, the basis for agriculture (de Boer & van Ittersum, 2018)). This is based on the premise that food production will, for the foreseeable future, have priority over other uses of biomass (e.g. the production of bioenergy or biochemicals) because – in contrast to food – energy can be produced directly from a variety of other resources whereas humans require biomass to fulfil their nutritional needs.

Finally, the role of farm animals in the food system should be centred on converting by-products inedible to humans into valuable food, manure, and ecosystem services. The three principles guiding circular agriculture, as outlined by WUR (de Boer & van Ittersum, 2018) are thereby as follows:

1. Plant biomass is the basic building block of food and should be used by humans first;
2. By-products from food production, processing, and consumption should be recycled back into the food system;
3. "Use animals for what they are good at"; in other words, rather than have animals consume biomass edible for humans, e.g. grains, animals can convert "low-opportunity-cost feeds' (e.g. crop residues, co-products from the food industry, inevitable food losses and waste, and grass resources) into food, manure, and other products (de Boer & van Ittersum, 2018).

Practices

Potential practices (de Boer & van Ittersum, 2018) under circular agriculture include:

- Preventing nutrient loss through precision agriculture (described in Chapter 4);
- Preventing nutrient loss by breeding varieties of crops that can more successfully bind atmospheric nitrogen for their food, for instance leguminous plants;
- Using insects, worms, or fungi to convert currently unusable residues (e.g. straw and foliage) into nutrient-rich raw materials for animal feed;
- Having ruminants consume grass and herbs in pastures unsuitable for growing food (e.g. peat grasslands in the Netherlands);
- Using the manure from animals, as well as select crop residues, as a valuable source of organic material that replenishes the soil and prevents the loss of finite mineral resources;
- Producing better-quality crops in order to generate fewer by-products that will not be directly used as human food and/or produce higher quality by-products with a clear purpose for using them – i.e. producing dual-purpose food and feed crops;
- Using every part of the plant, thus moving from a focus on the highest yield of single crops to a focus on the highest total quantity of whole crops and mixtures of crops within one field;
- Intercropping and growing crops in the right sequence and at the right time as is vital for resilient crop rotation and managing yield increases or reductions;
- Advancing diversity in crop and variety mixes at different scales as a key principle in managing pests, weeds, and diseases in crop production;
- Closer interaction of crop and livestock production and inclusion of grass in crop rotation for a wider application of crop rotation and pest control;
- Algae and other aquatic biomass as promising to producing substantial amounts of biomass with specific qualities while contributing to the recycling of nutrients;
- Application of by-products in the field to improve and preserve soil quality, i.e. soil fertility, soil cover, avoidance of erosion;
- By-products used as feed for livestock or insects to produce food from animal sources;
- By-products used for the production of bioenergy, nutrient fertilisers, or renewable biomaterials to mitigate GHGs;
- By-products incorporated into the soil to sequester carbon and mitigate GHGs;
- Feeding animals with "low-opportunity-cost", quality feed;
- Breeding or selecting those animals most suited to transform by-products into quality food, manure, and ecosystem services;
- Biorefining and biological treatment of by-products to produce higher quality feed, or to transform by-products into viable food for humans.

Challenges and opportunities

Specific challenges relating to circular agriculture concern its potential for mainstreaming and uptake. For example, in The Netherlands legal obstacles exist resulting from policies that for decades promoted the maximization of production (van der Hoeven, 2019). Furthermore, according to WUR (de Boer & van Ittersum, 2018), the commendable goal of mainstreaming dual-purpose food-feed crops is difficult, as current crops have been selected to focus on one purpose at a time (e.g. protein production). A crucial bottleneck for circularity is the separation of side streams, for reasons of food and feed safety, as regulated by EU and national waste legislation. Global trade and markets also play a role (currently Europe continues to import feed and fertiliser), while consumer demand will ultimately inform the production level of animal protein as attitudes and ideas about healthy diets evolve. Adequate support for innovation is needed to bolster the creation of new markets in a circular food system – something which is already happening as the circular economy practices take root in other sectors.

In terms of sustainability, should circular agriculture be effectively implemented, this could satisfy environmental, economic, and social objectives. An interesting finding by van Zanten et al. (2018), and a potential opportunity for circular agriculture, is that in comparison with a vegan diet, a human diet including a certain amount of food produced by animals fed solely with 'low-opportunity-cost feeds' could free up about one quarter of global arable land. In a vegan diet scenario crop residues, co-products, or grasslands, would not be recycled back into the food system by animals and additional crops would need to be cultivated to meet the nutritional requirements for the human population. Efficiently and sufficiently closing the loop at a scale will likely always be difficult, however. Differences in agroecological and socioeconomic circumstances will affect at what scale it may be possible and indeed wise to close nutrient loops. Local will not always be better, either: cities, for instance, create a lot of waste that could be used as a valuable resource elsewhere, and transporting nutrients in large volumes may in this case justify emissions (de Boer & van Ittersum, 2018).

3.13 Ecological intensification

Definition

Various approaches to utilising improved ecological function to increase food production, while maintaining the sustainability of production systems, have been developed (Baulcombe et al., 2009; Struik et al., 2014, in FAO, 2019). These have been variously described as sustainable intensification, ecological intensification, agroecological intensification, and eco-functional intensification (FAO, 2019). Ecological intensification was **first used as a term in a 1986 publication by K. Egger** (Wezel et al., 2015), describing an approach that focused on soil fertility maintenance and the integration of crop and livestock production in an agrosylvopastoral system. It was not until 1999 that the definition had evolved to mean an "intensification of production systems that satisfy the anticipated increase in food demand while meeting acceptable standards of environmental quality" (Cassman, 1999 in Wezel et al., 2015). In recent years, however, the term has further evolved from an agronomical approach with a focus on yields to a multidisciplinary approach, integrating concepts such as ecosystem services and biodiversity.

Ecological intensification is thus an approach that aims to match or increase agricultural production yields as compared to conventional farming methods, while minimising negative impacts on the environment and on agricultural productivity, *by integrating the management of ecosystem services delivered by biodiversity into production systems* (Bommarco et al., 2013). While, according to Tittonell (2014), the definitions for ecological and sustainable intensification (see next section) do not differ much in concept, an important distinction in practice is that while sustainable intensification could focus at the scale of one single crop or farm and include food security (livelihoods) as a top priority, ecological intensification aims to make "*intensive and smart use of the natural functionalities of the ecosystem … to produce food, fibre, energy, and ecological services in a sustainable way*". Embedding nature in this way requires ecological intensification to consider the complexity of the landscape, beyond the farm or field.

At its core, and moving beyond a focus on yields, the approach strives to harness a better understanding of biological processes and systems for improving agricultural performance; to that end the FAO defines ecological intensification as a knowledge-intensive process, aiming for an *"optimal management of nature's ecological functions and biodiversity to improve agricultural system performance, efficiency and farmers' livelihoods*" (FAO, n.a.). The approach may be applied in **different regions, contexts, and production systems**.

Principles

Relying heavily on biological processes and striving to better understand and make efficient use thereof towards intensifying production, ecological intensification aims to achieve multiple goals, including:

- Biodiversity conservation;
- Improved soil fertility management with the help of biodiversity and key ecological processes facilitating nutrient recycling and balanced nutrient flows;
- Reduced pest and disease infestations based on a better understanding of the relations between organisms;
- Farming system resilience, through diversified plant breeding adapted to climate change and resource shortages (Wezel et al., 2015).

Further principles of ecological intensification, in relation to food systems and human factors, include:

- Decreased energy use (and thereby a reduction in GHGs and fossil fuel dependence);
- Recycling of by-products;
- Reduction in meat consumption, food losses and waste;
- Responding to consumers' expectations of product quality;
- Reducing negative health and environmental externalities;
- Increasing participatory involvement of stakeholders and collective decision-making (Wezel et al., 2015).

Practices

The principles of ecological intensification are translated into a wide range of practices, concerning:

- Cropping systems: mixed cropping systems, diversified crop rotation, use of cover crops, direct-seeding, and mulch-based cropping systems;
- Soil: conservation tillage, minimising soil compaction and soil detoxification;
- Pests: Integrated Pest Management;
- Nutrients: improved fertiliser and nutrient management, regulation and monitoring

of nutrient supply, "fertigation" (injecting fertilisers into the irrigation system);

- Biodiversity management: preservation and promotion of positive allelopathic effects (Wezel et al., 2015).

Challenges and opportunities

Specific challenges for ecological intensification may be linked to its need to embrace the complexity of the landscape. In contrast, sustainable intensification solutions (*see* Section 3.14) may be applied at the scale of a single crop or agricultural field (Tittonell, 2014). Consequently, the implementation of, or transition to, ecological intensification requires collective decision-making, institutional innovation, serious investment, and long-term commitment. As it currently stands, the model has yet to be proven adaptable or scalable, however global assessments of productivity levels indicate that investments into research for ecologically-intensive farming can pay off. Recent research (Project Liberation, 2017) has suggested that policy should target the broader landscape rather than the farm level only, and that further research is needed on how to reduce yield gaps by, for example, incorporating or focusing on harnessing specific ecosystem services that are tailored to specific agricultural contexts (through ecosystem-based adaptation) (FAO, 2017).

In terms of sustainability, with its strong focus on ecological processes and biodiversity conservation, the approach focuses primarily on environmental sustainability. As the understanding and scope of the approach has evolved, societal factors have also become interwoven into its underlying principles. Although the other main focus of the approach is an increase in agricultural yields, thereby targeting economic sustainability, the actual scalability of the approach has as yet not been ascertained. At the same time, ecological intensification advocates for a reduction of external, and environmentally-harmful inputs to the farm system, potentially lowering costs.

3.14 Sustainable intensification

Definition

Sustainable intensification **emerged as a concept during the 1990s** (Pretty, 1997; Cook et al., 2015)**, from efforts to increase the productivity of smallholder farms in African countries**. The term has since been adopted by governments, agribusiness and industry, and international organisations, who have applied and promoted the approach around the world (Mahon et al., 2017; Cook et al., 2015) (e.g. the Sustainable Crop Production Intensification from FAO (2016)). According to the FAO (2019), shortages of available agricultural land combined with the need to ensure sufficient and nutritious food for a growing global population have led to the development of an approach to increase food production without increasing agricultural land. The approach thus aims to address or reconcile the two goals of safeguarding global food security while reducing the environmental impacts of agriculture (FCRN Foodsource, 2018).

In 2009, the UK's Royal Society provided the now commonly accepted definition for sustainable intensification, as an approach wherein *"yields are increased without adverse environmental impact and without the cultivation of more land"* (The Royal Society, 2009), capturing the approach's underlying principles. The intensification of agriculture is, indeed, usually associated with increasing yields, particularly in the context of developing countries.

However, according to Garnett and Godfray (2012), sustainable intensification's primary goal is to raise productivity (increasing yields per unit of inputs, as well as per unit of 'undesirable' outputs, e.g. GHG emissions), therefore not necessarily increasing food production. Furthermore, several authors (Garnett et al., 2013) state that the approach "*denotes a goal but does not specify a priori how it should be attained or which agricultural techniques to deploy*". The approach may therefore 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) (FCRN Foodsource, n.a.).

Principles

Three principles (FCRN Foodsource, 2018) underpin sustainable intensification, namely:

1. Confining food production to existing farmland; based on the expectation that the demand for food is expected to grow with a growing population, this would also require an increase in yield per hectare.
2. Reducing environmental impacts; an increase in yield per hectare should not be attained with an increase in the use of chemical pesticides and synthetic fertilisers, however. Sustainable intensification aspires to intensify the productivity of agricultural land while reducing harmful inputs and keeping environmental impacts at a minimum.
3. Increased yields; touching on the previous two principles, increasing agricultural yield is considered to be the most challenging and also controversial of the aims – however it is important to keep in mind that the main aim of sustainable intensification is to increase "productivity", not "production".

Practices

To fulfil the aims as denoted by the three underpinning principles, sustainable intensification may draw from various kinds of practices (FCRN Foodsource, 2018). Different practices may fall under sustainable intensification, so long as they follow the aforementioned principles. Examples of practices include:

- Drawing from integrated approaches and agroecology, including practicing intercropping and other forms of diversification;
- Drawing from organic farming, i.e. fewer synthetic and external inputs, and closing the loop with on-farm nutrients and resources through the integration of crop and livestock farming;
- Drawing from precision farming, i.e. using robotics, AI, and big data to become more resource efficient and temporally and spatially precise;
- Drawing from urban farming (*see* Chapter 4), in particular vertical farming, and practicing resource efficiency as well as lowering land use through practices such as hydroponics, aeroponics, and LED-farming;
- Drawing from genetic improvement methods, ranging from selection and domestication through to base broadening and biotechnology;
- More efficient and sustainable use of greenhouses.

Challenges and opportunities

Specific challenges for sustainable intensification are linked to the wide range of practices that can be implemented to achieve its goals, which leads to a wide range of interpretations as to what may be considered a fitting practice within sustainable intensification. Common criticisms of the approach point out that sustainable intensification, in its inclusion of a wide range of practices, could allow for business as usual, or at the least, a looseness in defining the concept, making it too vague to be useful (FCRN Foodsource, 2018). For instance, without increasing agricultural land area, a farmer could convert a plot of farmland to grow more productive crops, leading to adverse effects on biodiversity. On a practical level, it is difficult to measure the effectiveness of the approach; while the "land equivalent ratio" is one means of measuring progress, the productivity of a system can also be measured in terms of the quantities of various inputs, outputs, and environmental impacts (FAO, 2019). Although it is often claimed that the goal is to increase "productivity" (versus "production"), criticism is also expended on the approach's call to increase yields. Common to all intensive and production-focused approaches, critics are quick to point out that, more than the need to produce more food, the real failure lies in socio-economic access to safe and nutritious food, as well as its distribution and waste (FCRN Foodsource, 2018). The approach is certainly context-specific, and in terms of Europe the point has been made that European agriculture is already very intensive, and the focus should therefore be on its sustainability (Buckwell et al., 2014; Rural Investment Support for Europe, 2014).

In terms of sustainability, following all the principles together should result, in theory, in an increase in yields attained not at the expense of the environment. In this way, it could be reasoned that the approach may be conducive to both economic and environmental sustainability. Nevertheless, there is criticism that there should be more of a focus on actively encouraging environmental benefits as opposed to solely avoiding negative impacts – which is often a distinction made between sustainable and ecological intensification (Tittonell, 2014) (*see* Section 3.13). Furthermore, criticism remains regarding the lack of consideration for social criteria, wherein in some contexts the concern remains that sustainable intensification methods may favour large corporations due to the techniques and inputs (e.g. knowledge, technology, seeds) that the approach requires (FCRN Foodsource, 2018). It should be noted that the goals of sustainable intensification, whether the focus is on productivity or production, may look very different between food-surplus and food-deficit countries, which ultimately may inform how much consideration the approach gives to environmental, economic, and social sustainability criteria.

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4. Supporting activities

The following are some of the activities that can play a role in the context of sustainable agriculture. They do not constitute an approach for sustainable agriculture per se (as outlined in Chapter 3), as indeed some are tools which have not necessarily been designed to contribute to sustainability, while some others are activities with a scope which extends beyond agriculture. Others are prominent tools and activities, which can fit under a number of approaches. Thus, the activities outlined in this section may be understood as supporting techniques or horizontal methods and measures, also for the previously outlined approaches. While many actors are looking to use these activities in support of sustainable agriculture, there are open debates about some of them at the moment.

4.1 Genetic improvement

Agriculture has always relied on species variety selection to make advances and adapt to changing needs and circumstances, having played a key role in shaping the development of all systems of agriculture throughout history.

According to the FAO (2019), while ensuring a quantity of product output remains a primary target for any genetic improvement effort in agriculture, there is a growing focus on a wider range of benefits arising from the practice, including those related to resistance to pests, diseases, abiotic stresses, nutrient density, and other aspects of product quality and adaptability. Moreover, genetic improvement can be used as a means to address threats to production caused by the reduced diversity of domesticated plant and animal populations.

It is important to note that the development of sustainable agriculture will be informed by the objectives behind these techniques – genetic improvement in and of itself is not necessarily striving for environmental goals, but it can have the potential to be used as a tool in this respect.

From the more traditional, to methods incorporating technological solutions, genetic improvement or optimization may consider practices including:

- **Selection**; involving the selection of species that perform well under natural conditions, are resistant to pests or do not have predators in the area, are indigenous or traditional to the area, and/or are of older, heirloom varieties of crops.
- **Domestication**; involving "*the development of new crop, aquatic, forest and animal species through deliberate breeding programmes or the continued selection and improvement of existing species from their wild progenitors*" (FAO, 2019), thereby increasing diversity through the introduction of new species.
- **Base broadening**; or "*increasing the amount of genetic diversity used to produce new varieties or breeds used in agricultural production*" (FAO, 2019), thereby increasing diversity within varieties, breeds, and populations, e.g. widening the genetic pool for breeding, mixing in wild species relatives, and cross-breeding.

- **New Breeding Techniques (NBTs) and gene modification through biotechnology**; involving the application of technologies for the genetic alteration of plants and animals, which may be done to increase their resistance, yields, or efficiency, with a potential focus on the characterization and conservation of genetic resources for food and agriculture.

4.2 Precision farming

Precision farming is often explained as a way to “apply the right treatment in the right place at the right time” (JRC, 2014). Concretely, precision farming uses technology to analyse and select variables that can influence the cultivated land’s productivity. It stems from the premise that any given land will always demonstrate some degree of variability, whether it be in the soil health, crop growth, climate conditions or presence of disease. Therefore, tailoring farming operations to compensate for that variability can improve results and minimise undesired impacts.

Precision farming has been made possible by the rapid development of ICT-based sensor technologies and dedicated software that provides the link between spatially-distributed variables and appropriate farming practices such as tillage, seeding, fertilisation, herbicide and pesticide application, and harvesting’ (EIP-AGRI, 2015b), as well as precision methods for livestock farming (Banhazi et al., 2012). Its rapid development following the 1980s may be attributed to the uptake of GIS (geographical information systems) or GNSS (global navigation satellite systems) in agriculture, a key feature and major enabler of ‘precision’ (JRC, 2014). The continuous emergence of new technological methods makes this practice the scene of major innovation and investment, and is set to develop in the years to come.

Precision farming aims to achieve the optimization of yields and quality in relation to the productive capacity of each site, better management of the resource base, a reduction in costs and inputs, and – if there are environmental objectives behind its application – it can also be positive in terms of environmental protection (Srinivasan, 2006). Precision farming can limit and reduce external inputs to the farm and reduce associated costs and, through better monitoring and response, protect and optimise yields and quality. Lower quantities of fertiliser and pesticides can help protect the environment, lower fuel use through curbing unnecessary usage of tractors and machinery, and help cut down emissions. Better monitoring and response actions may lead to improved production capacity at the site and could ensure more efficient land use (although this should not be at the cost of biodiversity). At the same time, for the technologies to function properly, the data centres which power much of them will require substantial energy consumption – should too many resources be needed to operate these centres, the environmental sustainability potential of precision farming could come into question.

The cutting-edge machinery and technologies used as precision farming tools (such as driverless tractors and sprayers with built-in computers) are very expensive pieces of equipment, often making the adoption of precision farming difficult for farmers operating on smaller farms, unless the service is provided by competitive farm contractors. With smaller farms less able to afford the transition, a growing division between small and big farms may lead to significant inequalities (Kritikos, 2017). Even for big farms, however, there is the potential increased dependency to service and machinery providers, also in terms of the property of the data. Moreover, implementing digital farming tools requires a powerful and constant internet connection and optimal network speed, something that is lacking in many rural areas. Many technologies have yet to be developed for reliable adoption, and even those technologies will come with the risk of failing and breaking down, potentially compromising a farmer's entire operation. With increasing amounts of data monitored and extracted, farmers will need to understand what data that they need and how to use it, requiring a training for very complex – and still evolving – technologies (EIP-AGRI, 2015b).

4.3 Mixed farming systems

Mixed farming (also known as diversified farming) is typically understood to be the mixing of livestock and crops on the same farm (Merriam-Webster, n.a.). Before the industrialization of agriculture specialised farms to focus on one or the other, this had been the norm. Today, mixed farming systems (MFS) are once again gaining popularity, with a recoupling of crops and livestock considered to be a viable way to optimise resource efficiency and limit negative environmental impacts, while maintaining agricultural productivity and diversifying sources of income (EIP-AGRI, 2017). According to the FAO (2001), mixed farming may be extended to include three types of farming: on-farm vs. between-farm mixing, mixing within crops and/or animal systems, and diversified vs. integrated systems.

As recoupling crops and livestock could optimise resource efficiency, researchers and policy makers see MFS as a possible alternative to specialisation. Using crops and grasslands for animal feeding and, in return, organic manure for fertilisation, MFS could recycle nutrients more efficiently than specialised systems. MFS could thus theoretically limit negative environmental impacts while maintaining agricultural production and diversifying sources of incomes. Still, existing models of European MFS are not performing well in economic terms compared to specialised systems: they face a low labour remuneration and higher workforce requirement, which questions their level of economic sustainability. There is thus a need to understand better whether MFS can contribute to all three sustainability dimensions of farming (environmental, economic, social), and to what extent (EIP-AGRI, 2017).

Similar to the mixing of crops and livestock on the same agricultural land, **agroforestry** is a popular practice that can provide a wide range of economic, sociocultural, and environmental benefits. It has the potential to raise incomes, improve security, conserve biodiversity and ecosystem services, as well as to mitigate climate change through increased carbon sequestration (Hillbrand et al., 2017). It involves land-use systems and technologies where trees are integrated on the same land together with crops and/or animals (in some form of spatial and/or temporal arrangement). According to the FAO (n.a.), through the integration of trees on farms, agroforestry diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. The FAO defines three main types of agroforestry systems:

- **Agrisilvicultural systems** are a combination of crops and trees, such as alley cropping or home gardens.

- **Silvopastoral systems** combine forestry and grazing of domesticated animals on pastures, rangelands, or on-farm.
- The three elements, namely trees, animals and crops, can be integrated in what are called **agrosylvopastoral systems** and are illustrated by home gardens involving animals as well as scattered trees on croplands used for grazing after crops are harvested (FAO, n.a.).

A number of the approaches covered in the previous chapter may consider mixed faming, agroforestry, or similar practices to integrate or diversify production - notably agroecology, nature-inclusive agriculture, permaculture, ecological intensification, low external input agriculture, circular agriculture, and biodynamic agriculture. For many of these approaches, this is done in a way that is holistic and considers the whole farm system. These approaches are thus based around the key principle underpinning integrated farming, wherein every part of the whole can influence another, and that when farm management addresses this, profitability can increase and pollution can be reduced (LEAF, 2014) (*see* following section). In any case, such a holistic view of the farm also requires a broad knowledge of different fields and might be more complex to manage for farmers.

4.4 Integrated farming tools

There are several relatively similar terms in this context, such as integrated farming systems (IFS) or integrated food and farming systems (IFFS), integrated crop-livestock systems and integrated crop-livestock-forestry systems, integrated farm management (IFM), integrated nutrient management (including integrated plant nutrient management), integrated crop management (ICM), integrated weed management (IWM), and integrated pest management (IPM).

In particular, **integrated farming systems** follow a holistic, whole-farm view to agriculture, based around the strategic planning and management of the farm. According to the European Initiative for Sustainable Development in Agriculture (EISA) (EISA, n.a.), which champions the term, integrated farming "*produces sufficient high-quality food whilst maintaining and enhancing biodiversity and our natural environment*". EISA considers harnessing the interconnectedness between agriculture and the environment, practicing resource efficiency (especially in terms of nutrient flow), and ensuring profitability to be the cornerstones of achieving a farm's sustainability (EISA, 2012). When evaluating an efficient use of resources on a farm, it becomes clear that the interconnectedness between the farm and the environment is so complex that one change in the management of the farm can affect another; for instance, altering soil tillage will inevitably affect fertilisation, cropping sequence and crop protection. Thus, integrated farming takes on a systems overview when implementing changes to the farm; as a tool it enables knowledge-based flexibility and is based on informed management processes, allowing the farmer to identify adverse effects such as soil erosion or nutrient leaching and adjust this in the system. In animal husbandry, it is an effective tool to maintain animal health and welfare, while at the same time reducing environmental impacts (EISA, 2012).

EISA's paper proposing a European Integrated Farming Framework was issued in 2012, with the concept first presented in Brussels already in 2003 (EISA, 2012). The Initiative titled 'Linking Environment and Farming' or 'LEAF' (LEAF, n.a.), in the UK, follows a similar approach; its wheel of actions is comprised of 9 components, in comparison with EISA's 11. LEAF has its own label, the LEAF Marque, described as an environmental assurance system recognising sustainable farmed products. Similarly, the United States Department of Agriculture (USDA) came out with their Integrated Farm System Model in 2017 (USDA, n.a.), emerging from their development of a simulation model of the dairy forage system that began in the early 1980s. The model was developed as a response to the need for a research tool that integrates the many physical and biological processes on a farm (USDA, 2017).

Integrated pest management (IPM) is another popular tool, and a practice under many approaches to sustainable agriculture. It considers all available plant protection methods in an effort to "manage insects, weeds and diseases through a combination of cultural, physical, biological and chemical methods that are cost-effective, environmentally sound and socially acceptable" (ECPA, n.a.). In the EU, IPM is a cornerstone of the Directive on the Sustainable Use of Pesticides (European Parliament and Council, 2009), and in the US it is promoted under the Pesticide Environmental Stewardship Program (PESP) (PESP, n.a.). The FAO promotes the tool as the preferred approach to crop protection, with the FAO IPM programme currently comprising three regional programmes (in Asia, Near East and West Africa) (FAO, n.a.).

4.5 Pasture-based and free-range farming

Both pasture-based and free-range farming seek to address societal demands for lower impacts on the environment (for pasture-based farming especially in reducing greenhouse gas emissions), for greater animal welfare, and for less intensive production, in favour of stable production coupled with a fair income (EIP-AGRI, 2019). In contrast with raising animals on 'factory farms' and in enclosed spaces, they involve allowing animals to roam and move around freely, thus closing the loop into a renewable cycle where the needs of one element are met by the wastes of another (Foodprint, n.a.). This could be seen as a move back towards more traditional ways of farming, such as pastoralism, and away from industrial agriculture, which has separated animals from plants and resulted in, on the one hand, depleting soil, and on the other producing animal waste in toxic amounts (Foodprint, n.a.). Pasture-based and free-range farming were in fact predominant until the discovery of vitamins A and D in the 1920s, and breakthroughs in nutritional science, which introduced fortified animal feed and allowed confinement practices to become successful at a commercial scale (Heuser, 1955).

While pasture-based and free-range farming both undertake similar approaches, pasture-based farming typically concerns ruminant livestock while free-range refers to granivores such as poultry and pigs. With the aim of ensuring the protection of the environment and climate, animal welfare, and human health (Foodprint, n.a.), pasture-based and free-range systems involve practices (Foodprint, n.a.; EIP-AGRI, 2019) such as grazing and rotational or strip grazing, growing diverse herbs and crops on the pastures, using manure as fertiliser, practicing silvopasture, and precision livestock farming which enables, for example better monitoring of livestock movement. With less time spent in stables (and thereby a lower chance of faeces reacting with urine) ammonia emissions are reduced, manure deposited by the animals can naturally improve the fertility of the soil and enable healthy grasslands, and animals can roam freely and choose to eat plants and insects that they naturally digest. Not only does this help make the animals healthier and less stressed than those raised in confinement, but consequently also the meat, eggs, and dairy products from pasture-based and free-range animals have been shown to be healthier and more nutritious.

Although these systems may necessitate fewer inputs, they require a significant amount of labour (e.g. bringing the cattle out to graze, collecting manure, collecting eggs laid outside), as well as supervision (e.g. free-range chickens can fall prey to natural predators). There is, however, market demand and thus higher prices for meat, eggs, and dairy products from these kinds of farms. This demand is on the rise, with an increasing number of consumers willing to pay the price differential. There are potential difficulties when it comes to the market as well, however, as what qualifies as "pasture-based", "grass-based" and "free-range" may differ according to legislation (in the EU, for instance, for eggs to be marketed as free-range, hens cannot have been indoors for more than 12 weeks at a time) (Nicholson, 2017). Outbreaks of diseases affecting the production of animals can present challenging situations for farmers. For example, during the avian influenza outbreak the EU allowed producers of free-range eggs to continue marketing their eggs as such even if their hens had restricted access to open-air runs for up to 16 weeks (European Commission, 2017). Stricter rules may naturally be more difficult to comply with, however whether strict or lenient, the sheer number of differences between legislation around the world can present issues with trade as well as, perhaps more importantly, impair consumer understanding and erode consumer trust.

While there are some clear environmental benefits to these approaches, grazing is an extensive form of farming, using a significant amount of land, and can be argued as having its own impact on the landscape. Although extensive grazing plays a very important role in maintaining certain types of biodiversity, farmers could end up in practice with high livestock densities per hectare, which would exert certain pressures on biodiversity. In the longer term, for the sake of the environment and climate change, human diets should surely transition away from high amounts of animal protein and consumer demand is already trending in that direction (Monbiot, 2019). The sustainability of farming activities focusing on the production of animal protein may therefore be brought into question, although this would not apply to smaller amounts of higher quality animal protein production in low density levels.

4.6 Landscape and ecosystems approaches

As a way to ensure sustainable land management not only for agriculture, but also more broadly, the **landscape approach** considers a greater area than the farm proper. According to WUR (Verhagen et al., 2017), it seeks to provide ways to manage land towards achieving social, economic, and environmental objectives, in areas where agriculture, mining, and other productive land uses compete with environmental and biodiversity goals. It was developed as a framework for landscape-level conservation and, in terms of sustainable agriculture, combines conservation, food production, and development efforts in the landscape context. According to the FAO (2019), landscape management involves practices that support the maintenance of biodiversity-friendly farming systems and a diversity of landscape mosaics within and around production systems.

Practices falling under a landscape approach specifically relating to sustainable agriculture include the management of corridors, hedges, field margins, windbreaks, woodland patches, forest clearings, waterways, ponds, and other biodiversity-friendly features of the production environment (FAO, 2019). Agroforestry, silvopasture, and sustainable grazing practices such as livestock grassland-based production systems, are often used to manage and maintain open and diverse semi-natural landscapes. From the aforementioned approaches and activities, High Nature Value (HNV) farming and pasture-based / free-range farming are often considered landscape, or landscape management, approaches.

Similar to the landscape approach, working with nature and encompassing a wider set of considerations than those confined to the farm area, the **ecosystems approach** is another supporting tool for sustainable agriculture. The ecosystem approach emerged at the second meeting of the Convention on Biological Diversity (CBD) held in Jakarta in November 1995 (Secretariat of the Convention on Biological Diversity, 2004), and quickly became part of the core framework or action under the Convention. The CBD describes the 'ecosystem' as "*a dynamic complex of plant, animal and micro-organism communities and their non-living environment acting as a functional unit*" (FAO, 2003), and considers that a general application of the approach will help achieve a balance of the three objectives of conservation, sustainable use, and the fair and equitable sharing of the benefits from the utilization of genetic resources. The Convention proposes 12 key principles to an ecosystem approach (Secretariat of the Convention on Biological Diversity, 2004). The approach can be applied in many sectors, including agriculture, with a focus on ecosystem services and biodiversity.

Several kinds of practices (FAO, 2016; Morris, n.a.; IEEP et al., 2017) may be considered in an ecosystem approach specifically applied to agriculture, including efficient water management, green infrastructure mechanisms, integrated pest management, agroforestry, and precision farming for resource and nutrient monitoring. With the greater ecosystem in mind, a challenge common to all ecosystem approaches lies in having to organise and facilitate collaboration among various disciplines, communities, and actors that are stakeholders in the ecosystem unit (Richter et al., 2015). For an ecosystem approach to agriculture, this means bringing together the wider community, including stakeholders from the agricultural and environmental communities. This can mean bringing together opposing views and objectives, though it can also be seen as an opportunity to enhance dialogue.

4.7 Supporting socio-economic activities

The following activities do not focus on agronomic practices, nor food production per se, but are often mentioned as approaches (linked) to sustainable agriculture. They may be understood as taking on more of a socio-economic angle, supporting sustainable agriculture by strengthening the local dimension and empowering communities, to tapping into existing streams of resources or uncovering new streams of revenue in order to boost the economic sustainability of environmentally friendly approaches. Three such activities for sustainable agriculture, explored in the following sections, are well-established and/or fast gaining ground.

Mentioned in some of the approaches previously (*see* sections on *Permaculture* and *Biodynamic agriculture*) **community-supported agriculture** has been gathering attention and experiencing considerable growth in many countries around the world. Developed in Japan and Switzerland in the 1970s and gaining popularity in the United States in the 1980s, it has since spread across Europe (IFOAM, n.a.). In 2008, the International Network of Community Supported Agriculture (URGENCI) (URGENCI, n.a.) was formed, leading the connection and promotion of community-supported agriculture worldwide.

According to IFOAM, community-supported agriculture is underpinned by four fundamental ideas:

- Partnership - a mutual commitment on the part of farmers to supply, and consumers to buy, the food produced during each season;
- Local exchange - an effort to re-localise the economy;
- Solidarity - actors share the risks and the benefits associated with healthy production that is adapted to the natural rhythm of the seasons and is respectful of the environment, natural and cultural heritage, and health;
- The producer/consumer tandem - establishing direct person-to-person contact and trust, with no intermediaries, hierarchy, or subordination.

Further principles are outlined by URGENCI, including the principles of mutual assistance, accepting produce, mutual concession in the price decision, deepening friendly relationships, self-distribution, democratic management, learning among each group, maintaining the appropriate group scale, and steady development (URGENCI, n.a.).

Community-supported farms thereby have a strong focus on the local dimension, producing and supplying at the local scale and involving short supply chains. Consequently, they are typically smaller scale, grow and raise locally-adapted species, produce seasonally, and are as such sustainable through their smaller footprint, their self-sufficiency, and their ability to support and empower the community and individuals through community-supported partnerships.

Urban farming, or urban agriculture, can be seen as a way of bridging the gap between urban and rural, bringing farming into cities. The trend is not new, as it has in the past been associated with times of crisis and food shortages; today's increased uptake of agricultural practices in cities may be attributed to the recent financial crisis (McEldowney, 2017). However, its growing popularity may also be as a response to the climate and environmental crises, our increasing detachment from the global food production and distribution systems, and the sense of urgency to become more self-sufficient in the face of global disruptions.

Urban agriculture today can take on many forms, ranging from home, school, and community gardens at a smaller scale; to rooftop (Harrap, 2019), vertical and indoor farms practicing resource efficiency at a larger scale. Thus, it takes on a social dimension by bringing communities together to produce food locally, sustainably, and self-sufficiently, as well as an economic dimension, in that urban agriculture is both embedded in and interacting with the urban economic and ecological system. Making use of the available resources – both material and human resources are highly concentrated in cities – urban farming uses urban residents as labourers. It makes use of typical urban resources (such as organic waste as compost and urban wastewater for irrigation), is able to establish direct links with urban consumers, become a part of the urban food system, and have both positive and negative direct impacts on urban ecology (McEldowney, 2017). Short supply chains are therefore prominent here, too.

Innovation is another key component of urban farming, for vertical and indoor farming in particular, where systems such as hydroponics, aeroponics, and LED-farming contribute to the uptake of sustainable farming practices (McEldowney, 2017). These are closed and tiered systems, based on very careful nutrient supply and recycling, tight biosecurity and biocontrol for pests, a reliance on solar, biomass or biogas energy, with practically zero air or water pollution, and close proximity to direct consumption and logistical distribution centres.

Some key benefits of urban agriculture include its contribution to employment, the development of small-scale rural entrepreneurs, improved education and health, and social inclusion. Its direct impacts on urban ecology, bringing in more green and diverse spaces into the urban environment, can lead to increased urban biodiversity, a reduced risk of flooding, better air quality, carbon sequestration, and temperature cooling. At the same time, certain drawbacks to the approach can be linked to a lack of entrepreneurial skills, barriers to cooperation with more traditional farmers, and challenges achieving and maintaining profitability. Urban farming may compete for land with other urban functions and is influenced by and dependent on urban policies and plans. This makes local and community involvement, organisation, and management essential.

Like urban farming, **agritourism** brings the urban and rural spheres closer together. It brings visitors, usually from the cities, to the countryside, allowing them to experience and learn about farming. As defined by the University of California (2017), agritourism is any income-generating activity conducted on a working farm for the enjoyment and education of visitors. Such income-generating activities may include educational activities, hospitality services, outdoor recreation, alternative marketing, and the creation or sale of value-added products.

A means of diversifying farmers' income, agritourism can play a role in supporting and maintaining the land and its resources. Visitors (or agritourists) are typically drawn to experience local, healthy, biodiverse, traditional, and/or innovative farming systems. Furthermore, these typically smaller-scale farms are likely to follow one of the sustainable approaches to agriculture as described in the previous sections, and can introduce agritourism as an additional stream of revenue. Through this supplementary income, and through raising awareness of sustainable farming practices, agritourism can in turn support and sustain sustainable agriculture.

Today, numerous platforms exist to connect agritourists with farm stays, such as FarmStayPlanet (FarmStayPlanet, n.a.) or Agritourism World (Agritourism World, n.a.). Furthermore, through the World Wide Opportunities on Organic Farms (WWOOF) network (WWOOF, n.a.), farms can offer prospective visitors longer-term stays (including room and board), and opportunities to learn about organic/biological growing and farming. In exchange, WWOOF volunteers work on the farm, providing additional labour over a longer term.

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5. Concluding remarks

As mentioned at the outset, the purpose of this report was to try to demystify and clarify some of the many terms relating to sustainable agriculture. In the process of reviewing the literature, learning about some of the main approaches, and summarising them for this report, what might have seemed like confusion before has resolved, in fact, into a good degree of consistency. The approaches described in this report may each consider sustainable agriculture from a different angle, and thus do not necessarily capture everything to the same degree. Nevertheless, **the different approaches to sustainable agriculture may share more similarities with each other than they do with conventional practices or approaches to agriculture**.

As difficult as it may be to draw meaningful comparisons between the approaches on the basis of their principles, one may effectively do so when inferring about their overarching goals. **The approaches have certain goals in common, such as striving for sustainability, which includes environmental aspects but also socio-economic considerations**. They all strive for sustainable agriculture, including a better state of the environment, healthy food, and a good quality of life for the producers. As such, these approaches can be considered to be, in principle, an improvement over conventional agriculture which, in the longer term, could negatively impact the environment and create conditions under which it is difficult for farmers to be competitive. Many link healthy food as an outcome and benefit of their environmentally friendly approach. A number of approaches seek to practice a more 'ethical' way of farming, in many cases also when it comes to animal welfare. A number of approaches strive to see the value chain captured more closely by farmers, and specifically smallholders and family farmers. Although growth in and of itself is not necessarily a goal, a number of the approaches may receive criticism due to their perceived limited profitability and scalability.

As some of the approaches have fewer strict rules in place, leaving things a bit more open and flexible in terms of application, this leaves room for interpretation. It is not entirely incorrect to say that **this room for interpretation can cause a degree of confusion and misunderstanding, potentially leading to the suboptimal implementation of a given approach**. On the other hand, and what is arguably more likely, those implementing an approach will define or understand it in their own way because of their own unique perspectives, goals and objectives. When it comes to sustainability, for instance, some might prioritise economic sustainability over environmental, or vice versa. In any case, it is important to bear in mind that it would be difficult or impossible to argue that the implementation of an approach qualifies as "sustainable agriculture" if it does not fulfil environmental goals.

The objectives behind the implementation of a given approach are therefore crucial. This is true for any of the approaches examined in this report, and perhaps especially those receiving criticism for allowing the continuance of "business as usual", or being accused of potentially causing perverse outcomes for certain aspects which are not the core focus of the approach. The objectives are particularly crucial when it comes to some of the technological solutions described in Chapter 4. Technology, in and of itself, is not an end but rather a means to one. Depending on the objectives behind their adoption, some tools and activities, such as precision farming, vertical (urban) farming, and the more technologically innovative kinds of genetic improvement, can be impactful for sustainable agriculture. Surely, this is a direction in which some industry is headed already. With the right measures taken to ensure environmental sustainability in all respects (including e.g. soil, water, biodiversity, and climate), and with the adoption of the technology made feasible (in terms of knowledge) and available (in terms of costs) to practitioners at the beginning of the food value chain, these solutions could be promising also for economic as well as social sustainability.

Many of the more holistic approaches aim to address the same issues through their practices, i.e. restoring soil health, reducing resource consumption (closing the loop through optimising on-farm resources), minimising vulnerability to pests in environmentally-friendly ways, reducing pollution and GHG emissions, and protecting and restoring biodiversity at multiple levels. There is a widely shared understanding of the problems, and a largely overlapping set of solutions. **Many of the approaches share similar environmentally-friendly practices**, which can be helpful for different aspects, including biodiversity**.** In particular, the following are repeated in most of the approaches' descriptions:

- **Crop rotation;**
- **The inclusion of cover and companion crops;**
- **Mixed crop and intercropping;**
- **The reduction of synthetic pesticide and mineral fertiliser use;**
- **No or minimal tillage;**
- **Lower livestock densities, managed grazing, free range.**

Other practices also mentioned in a wide range of approaches include **crop diversification, mixing farming and forestry, mixed crop and animal farming, nutrient balancing, recovery and reuse, or the inclusion of landscape elements such as hedgerows and flower strips**. This list of practices might be longer for some of the approaches, bearing in mind that the lists of practices are in most cases, as in literature, non-exhaustive. We can conclude that **the practices mentioned above in bold can be considered "sustainable agricultural practices"**. We cannot claim to be exhaustive in our description of practices as they pertain to approaches, however we can infer that most approaches to sustainable agriculture might include or support the key practices listed above.

Throughout Chapter 3 we have looked into some specific challenges per each approach, and have tried to assess their potential or their emphasis on all three pillars of sustainability. We note, however, than **their similarities extend to certain common challenges**. These common challenges have to do with costs, profitability, productivity, scalability, uptake, knowledge, and in many cases, environmental sustainability - despite that being a key, overarching goal of each approach. Many of these challenges are interlinked, i.e. costs are inevitably linked to profitability, scalability, and so on. At the same time, this also means that addressing one challenge can end up addressing a number of them.

A number of approaches have been criticised as being costly, particularly in terms of labour and knowledge. It is indeed the case that many of the approaches require a significant amount of knowledge to implement and manage, and this is not always easy to obtain. Related to this **requirement for knowledge**, but also related to the decrease in the use of certain external inputs including chemical fertilisers and synthetic pesticides, is the **need for greater inputs in terms of labour**. A challenge inextricably **linked with costs is not only profitability, but also productivity**. Yield gaps are a much cited issue for a number of the approaches, impacting their economic sustainability. Indeed, moving away from chemical fertilisers and synthetic pesticides has an impact on expected yields. Moreover, specialization has become the more profitable avenue the world over, heavily driven over time by economics and technology, and dominating modern farms, markets, and policies. A number of approaches, like for instance agroecology, on the other hand, include the promotion of the production of a variety of locally adapted products rather than large volumes of one or a few standardised species and varieties.

Linked to the challenges of associated costs, productivity, and profitability, are **challenges of uptake and scalability**. Standards for a number of the approaches are not always clear or defined, which presents difficulties for uptake, much less for building a market or label that would enable substantial scalability. Where a market and label are established, premiums may well outweigh the costs of the approach, although it could be argued that premiums may only be in place whilst the approach remains niche. In any case, building and maintaining a strong label is not entirely easy in an age of label fatigue. When it comes to uptake, in addition to the potential barriers to entry in terms of costs such as labour and knowledge requirements, the stringent rules of certain approaches could prove difficult to adopt for prospective practitioners. Additionally, some of the approaches are younger than others, but whether that is the reason or not, many of the approaches are still based more squarely in theory than practice, or consider qualitative, rather than quantitative, criteria.

When considering the aforementioned challenges, it is important to keep in mind the recognition by scientists, based on recent IPBES conclusions (IPBES, 2019), that nature and its contributions to people can be safeguarded only by transformative change to a sustainable global economy. In this context, **potential costs and/or a reduction in profitability might be mitigated through public support or private investments in a transition towards sustainable land use; the short-term savings of inaction will otherwise likely be outweighed by resultant longer-term societal and material costs**.

It is important to note that the approaches to sustainable agriculture that have managed to do well in terms of costs (and thus profitability, scalability, and uptake as well) have been those with strong markets in place (e.g. organic farming). It should also be noted that most conventional agricultural practices are in fact receiving public subsidies, without which their profitability and sustainability might also be compromised. It can be concluded that **to ensure the path to sustainability is a just transition, it is important to consider public and other support**, also in terms of knowledge-building. As for the issue of an approach being labour-intensive, perhaps this could also be seen as an opportunity to foster vibrant rural areas as well as generational renewal and reduced unemployment.

A crucial factor underpinning a **common challenge related to knowledge is the lack of important metrics and indicators**. Not only do farmers need knowledge support to facilitate uptake and implementation (as mentioned, many approaches are knowledge-intensive), but a lack of evidence of the benefits of the approaches will convince neither farmers, consumers, nor policy. In some cases the environmental impacts or benefits of certain solutions are presently not easily measurable, and thus difficult to ascertain. **The lack of joint metrics is crucial, as a basis on which to reward farmers** – hard work going unrecognised, or there being significant lag between changes on the ground and them being acknowledged as eligible for support higher up, can be frustrating and discouraging.

As every approach has its own angle, a particular approach might have **challenges giving all crucial environmental aspects the same level of consideration – i.e. soil, water, biodiversity, and the climate** being the major aspects. While in some cases this might mean simply less of a focus on a given aspect over another, in other cases a sole focus on one aspect may lead to perverse, negative outcomes for another – true environmental sustainability would need to consider and strive for the better state of all key aspects in a balanced, integrated manner.

As we have seen, each of the approaches described in this report is addressing sustainable agriculture from a somewhat different angle. **Each of these approaches, therefore, might be valid in a given set of specific circumstances.** In this context, it is important to highlight that every farm (and farmer) is different, therefore these approaches could be seen as mainly providing a basket of options to farmers. Reflecting on the key questions pertaining to sustainable agriculture as outlined in the introduction of this report (*the how, what, how much, where, and when?*), when choosing *how* to produce food, or in other words which particular approach to sustainable agriculture to implement, in terms of environmental sustainability, two important questions will need to be considered by practitioners:

- First, the question of **spatial considerations, or *where*** – is this approach best suited for the landscape and environmental conditions in which it would be implemented in? For instance, an arid environment with degraded soil conditions might obtain the highest environmental benefits from applying conservation agriculture (or other soil-focused measures), while farming in an area surrounded with wildlife and nature, and even protected areas, might think about agroecology or introducing landscape elements on its perimeter, and maybe implementing ecological or sustainable intensification on the existing farmland.
- Second, the question of **temporal considerations, or *when*** – will implementing this approach mean this environment is better off than before? This question considers the issue of land conversion, where any approach might be a step forward or backwards, depending on what it replaces. Replacing a mix of less productive crops where biodiversity is thriving with one highly productive crop or even an orchard for organic apples, despite being grown in a sustainable way, might negatively impact the biodiversity as well as water and soil conditions previously on that land.

Other considerations about the given social and economic sustainability of an approach will also be fundamental. When choosing what approach to implement, practitioners will surely consider the aforementioned challenges, including costs, labour and knowledge requirements when it comes to uptake. The approach will need to be viable from an economic standpoint, wherein any available premiums and subsidies, and the strength of the market in terms of demand and willingness to pay, are all critical factors; practitioners, or producers, will also consider the demand and enabling conditions in place. With this in mind, two further questions need to be addressed, though not by practitioners alone; rather, by stakeholders along the food value chain and the wider society.

- The question of ***how much* we produce**, linking back to the challenge of productivity and yield gaps, must consider the immense amounts of food waste we are witness to today. How much *should* we be producing? We cannot speak about production without talking about consumption, but this cannot be limited to, for example, raising consumer awareness about waste. We should also consider the role that legislation and public subsidies, private investment, as well as the global context of our food system, plays in shaping the current nature and levels of production and demand. In any case, producing the food needed to feed the world is unlikely to be the primary goal that many farmers would have – rather, their main concern might be to ensure good living conditions and wages from the food that they produce. When speaking about the social and economic sustainability of the approaches, this is more likely to be secured with an emphasis on livelihoods farthest down the food value chain, as well as generational renewal – rather than on profit, currently captured higher up the chain.

- The question of ***what* we produce** should take into account similar considerations. A number of the approaches to sustainable agriculture may produce healthier, more nutritious food, and in many ways this may be in response to the growing demand for healthier food as well as animal welfare – we also note a rise in the availability of vegetarian and vegan food products as a response to evolving consumer tastes. In the same vein, however, impacting what we produce does not stop at raising consumer awareness and facilitating the demand for healthy and nutritious food. The lower costs of highly processed and unhealthy foods, which can imply hidden societal costs including proportionately high environmental footprints, are a major issue affecting demand and shaping our global food system, which could be helped through better regulation along the food value chain.

While the questions of *where* and *when* may consider the suitability of an approach within a particular, local context, it becomes apparent that the questions of *how much* and *what* outline the global dimension of our food system. Indeed, not only must the transition to sustainable agriculture consider more than merely production, it must acknowledge the fact that at the moment our food system is global. **It is important to note, but also crucial to further explore, the many interdependencies as well as issues along the global food value chain**, in order to arrive at practical and actionable ways in which to set this transition in motion. This will include looking into global consumption patterns, what exactly impacts demand, our key trade flows, and linked to all of this, the externalities and ecological footprint of our global food system, among other issues. Local, regional, and national activities and policies will continue to influence the global picture, and vice versa. In this respect, **the COVID-19 crisis has shown some interesting examples of how global supply chains may have given way to more local production and consumption chains in food systems** as well as in other areas (Foote, 2020; Matei, 2020).

Whether we look at this bigger picture, or whether we refocus on how we produce our food, the same crucial stepping stone on the path to this transition appears: **the need to find a common vision for what sustainable agriculture should look like in the future**. This is a fundamental question, considering the main societal goal for agriculture to produce food, the necessary use of land for this purpose, and the negative impacts that this activity can have on the environment. **This report shows that different approaches exist, that they have a number of important commonalities, but also that their diversity is a strength in itself.**

When it comes to implementation, the choice of approach depends very much on local contexts and specific priorities. **The challenge for policymaking is to enable dialogue and create the (market or regulatory) environment that will help define priorities according to local contexts, helping farmers follow the societally desired path**. **Underpinning all of this and helping to inform these choices is the need for common metrics to ascertain and monitor the environmental performance of the various approaches, which are currently lacking.** Considering that the production of healthy food at affordable prices with environmental protection at the core is crucial for our survival as a species, addressing these challenges is the most important step we need to take for our common future, right now.

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INTERNATIONAL UNION
FOR CONSERVATION OF NATURE

EUROPEAN REGIONAL OFFICE
Boulevard Louis Schmidt 64
1040 Brussels
Belgium
Tel: +32 2 732 82 99
Fax: +32 2 732 94 99
www.iucn.org