HLPE REPORT 14

Agroecological and other innovative approaches

for sustainable agriculture and food systems that enhance food security and nutrition

A report by

The High Level Panel of Experts

on Food Security and Nutrition

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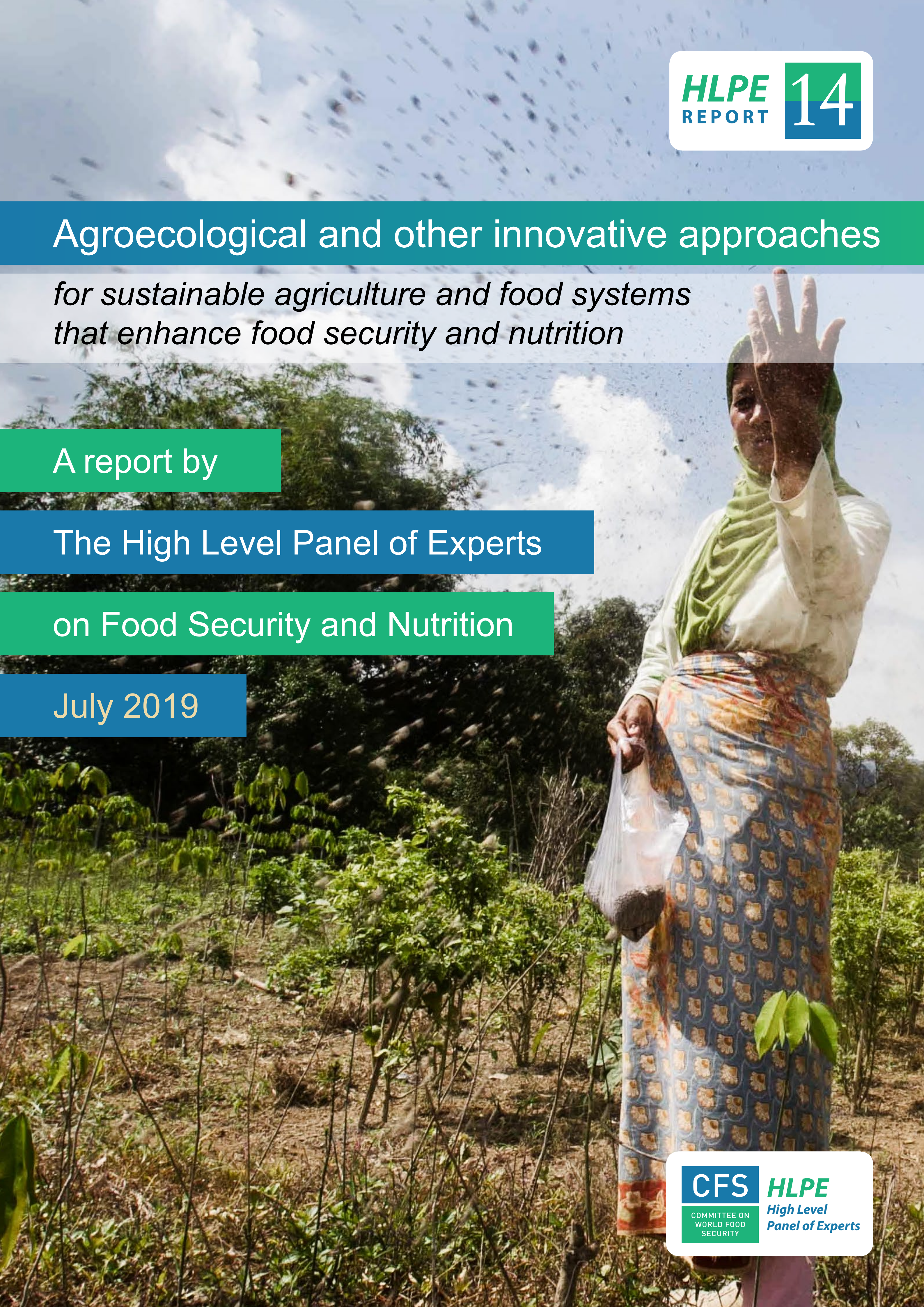

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FOREWORD

The High Level Panel of Experts for Food Security and Nutrition (HLPE) is the science–policy interface of the Committee on World Food Security (CFS) that is, at the global level, the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition (FSN).

The HLPE reports serve as a common, evidence-based starting point for the multi-stakeholder process of policy convergence in the CFS. The HLPE strives to provide in its reports a comprehensive overview of the topics selected by the CFS, based on the best available scientific evidence and considering different forms of knowledge. It strives to clarify contradictory information and knowledge, to elicit the backgrounds and rationales of controversies and to identify emerging issues. The HLPE reports are the result of an inclusive and continuous dialogue between the HLPE experts (Steering Committee, Project Team, external peer reviewers) and a wide range of knowledge-holders across the world, building bridges across regions and countries, across scientific disciplines and professional experiences.

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The global food system is at a crossroads. A profound transformation is needed at all scales in the face of demographic changes, increased pressure and competition over renewable resources, increasingly severe consequences of climatic changes and the loss of biodiversity. Such a transformation in what is produced and how it is produced, processed, transported and consumed is required to achieve Sustainable Development Goal 2 (SDG2) to “end hunger and all forms of malnutrition” by 2030, building on the four pillars of FSN.

The global agricultural and food systems are currently not meeting the world’s expectations for sustainability. Beyond declines and rises and despite a global increase in food availability, the number of people suffering from hunger has not significantly changed during the last 40 years. Worldwide, 821 million people were undernourished in 2018. This is all the more difficult to accept when one realizes that the majority of them are food producers and workers in precarious and difficult working conditions, affected by direct and indirect economic impacts of food systems. In addition, malnutrition, in its different forms (undernutrition, micronutrient deficiencies, overweight and obesity), now affects all countries. One person in three is malnourished and, if current trends continue, one person in two could be malnourished by 2030.

These tensions are likely to be exacerbated as food systems will continue to face complex and mounting challenges, including demographic and climatic changes, political instability, conflicts and increased pressure on natural resources (land, water, biodiversity, etc.) and ecosystem functions.

Sustainable food systems are needed to ensure appropriate food production and reduce losses and waste, while also safeguarding human and environmental health, political stability and better livelihoods with less environmental consequences.

At the same time, there are growing concerns around the political dimensions of food systems, including concentration in the industry and retail sectors, power imbalances and a lack of democracy in their governance, lack of transparency and accountability, and issues around access to and control over natural resources, including land, water, energy and genetic resources.

Agroecological and other innovative approaches are thus increasingly called upon to play a greater role in contributing to achieve global FSN. They are becoming increasingly prominent in debates around sustainable development because of their ambition to connect environmental sustainability and social innovation, production and consumption, global concerns and local dynamics through the support to locally adapted solutions based upon participation and the mobilization of local knowledge.

In this context, in October 2017, the UN Committee on World Food Security (CFS) requested the HLPE to produce a report on “Agroecological approaches and other innovations for sustainable agriculture and food systems that enhance food security and nutrition” to inform its discussions during the 46th CFS Plenary Session in October 2019 and to build a better understanding of the roles that agroecological and other innovative approaches, practices and technologies can play.

This report and its recommendations aim at presenting decision-makers, in the different “spheres of society”, with evidence on the potential contribution of agroecological and other innovative approaches, practices and technologies to design and implement sustainable food systems that contribute to FSN.

Central in this report are the concepts of transition and transformation. With this dynamic perspective, the HLPE explores the potential contribution of agroecological and other innovative approaches, practices and technologies.

Transitions are actually required to shape the profound transformation of food systems, to adapt the economic, environmental, political and technological paradigm, rules, institutions and practices that have become increasingly incompatible with present and future expectations, to move beyond “lock-ins” and the *status quo*.

In previous reports, the HLPE highlighted the huge diversity of food systems across and within countries. These food systems are situated in different environmental, socio-cultural and economic contexts and face very diverse challenges. Hence, actors have to design context-specific and adapted transition pathways towards sustainable food systems. As highlighted by these reports, such context-specific pathways combine technical interventions, investments and enabling policies and instruments. They involve a variety of actors at different scales. Yet, both incremental adequate transitions at local scales and more structural changes to institutions and norms at larger scales are required in a coordinated and integrated way in order to achieve the transformation of food systems towards FSN and sustainable development. Agroecological and other innovative approaches are also attracting attention because of their capacity to contribute to the design of scale-specific interdependent processes.

To meet the ambition and the expectations inherent in the CFS’s request, the report analyses the many available experiences and evidence. It points out the potential and limitations of technology, as well as gaps in knowledge. It also explores controversial issues. The intention is not to resolve them, but to clarify their nature and highlight where diverging views, narratives and values can bring different perspectives to a common goal. This aims at moving beyond potentially sterile dualities and at better formulating the choices to be made. The report finally looks at the design of institutional environments that can encourage transition pathways required to underpin the profound expected transformation of food systems.

As it brings together very different and contentious visions for the future of humanity, this report was certainly one of the most complex to prepare since the birth of the HLPE in 2010. It should therefore be considered as a milestone in an open ended process which ambitions to collectively address the challenges of sustainability. Understanding and assessing the issues that fuel the debate are key to allow policy-makers to design and implement concrete avenues towards sustainable food systems at different scales. My most sincere wish is that the scientific mediation and the expertise that has been gathered and organized through the preparation of this report can effectively contribute to FSN and to sustainable development at all scales.

This 14th report complements and strengthens the messages conveyed to the High Level Political Forum (HLPF) in July 2017 at United Nations Headquarters when contributing to the review of the achievement of SDG2. It helps to acknowledge the main recent shifts in the global agenda and priorities: on the one hand the need to move beyond a focus on food production and to consider the whole food systems to address FSN; on the other, the importance of looking at food systems as a strong lever to achieve Agenda 2030 for sustainable development in its entirety.

As I will soon be leaving the HLPE Steering Committee, I would like to acknowledge the endeavours of my predecessors and the contributions from my colleagues in shaping such a narrative. Ten years after the CFS Reform and the creation of the HLPE, it is now time to value such contribution and to look ahead. My strongest wish is to ensure the collective capacity and intelligence to design a forward-looking perspective enlightened by all previous HLPE publications. Reflecting on the current state of knowledge, highlighting the main areas of consensus and controversy, as well as the major challenges, gaps and uncertainties, this would be our legacy and confirm the visionary ambition of the HLPE in organizing a unique science–policy interface for achieving FSN and the Sustainable Development Goals.

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On behalf of the HLPE Steering Committee, I would like to acknowledge the engagement and commitment of all the experts who worked for the elaboration of this report, and especially the HLPE Project Team Leader, Fergus Lloyd Sinclair (United Kingdom) and Project Team Members: Mary Ann Augustin (Australia), Rachel Bezner-Kerr (Canada), Dilfuza Egamberdieva (Uzbekistan), Oluwole Abiodun Fatunbi (Nigeria), Barbara Gemmill Herren (USA, Switzerland), Abid Hussain (Pakistan), Florence Mtambanengwe (Zimbabwe), André Luiz Rodrigues Gonçalves (Brazil) and Alexander Wezel (Germany).

I would like to commend and thank the HLPE Secretariat for its precious support to the work of the HLPE.

This report also benefited greatly from the suggestions of external peer reviewers and from the comments provided by an even larger than usual number of experts and institutions, both on the scope and on the first draft of the report.

Last but not least, I would like to thank those partners who provide effective and continuous financial support to the work of the HLPE in a totally selfless fashion and thus contribute to keeping the impartiality, objectivity and widely recognized quality of its proceedings and reports.

Thanks to this high level of expertise and commitment, I am confident that this rich and comprehensive report will fuel an even richer policy convergence process and will ultimately help remove the lock-ins and inspire promising avenues by developing a common understanding of the essential challenges that humanity has to face.

Patrick Caron

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Chairperson, Steering Committee of the HLPE, 24 June 2019

SUMMARY AND RECOMMENDATIONS

Food systems are at a crossroads. Profound transformation is needed to address Agenda 2030 and to achieve food security and nutrition (FSN) in its four dimensions of availability, access, utilization and stability, and to face multidimensional and complex challenges, including a growing world population, urbanization and climate change, which drive increased pressure on natural resources, impacting land, water and biodiversity. This need has been illustrated from various perspectives in previous HLPE reports and is now widely recognized. This transformation will profoundly affect what people eat, as well as how food is produced, processed, transported and sold.

In this context, in October 2017, the UN Committee on World Food Security (CFS) requested its High Level Panel of Experts (HLPE) on FSN to produce a report on *"Agroecological approaches and other innovations for sustainable agriculture and food systems that enhance food security and nutrition"* to inform its discussions during the Forty-sixth CFS Plenary Session in October 2019.

In this report, the HLPE explores the nature and potential contributions of agroecological and other innovative approaches to formulating transitions towards sustainable food systems (SFSs) that enhance FSN. The HLPE adopts a dynamic, multiscale perspective, focusing on the concepts of transition and transformation. Many transitions need to occur in particular production systems and across the food value chain to achieve major transformation of whole food systems. Both incremental transitions at small scales and structural changes to institutions and norms at larger scales need to take place in a coordinated and integrated way in order to achieve the desired transformation of the global food system.

As highlighted by the HLPE (2016), transition pathways combine technical interventions, investments, and enabling policies and instruments – involving a variety of actors at different scales. In its previous reports, the HLPE (2016, 2017b) highlighted a diversity of food systems across and within countries. These food systems are situated in different environmental, sociocultural and economic contexts and face very diverse challenges. Hence, actors in food systems will have to design context-specific transition pathways towards sustainable food systems (SFSs). Moving beyond this context-specificity, the HLPE (2016) identified the three following intertwined operational principles that shape transition pathways towards SFSs for FSN: (i) improve resource efficiency; (ii) strengthen resilience; and (iii) secure social equity/responsibility.

This report starts from the recognition of human rights as the basis for ensuring sustainable food systems. It considers that the seven PANTHER principles of Participation, Accountability, Non-discrimination, Transparency, Human dignity, Empowerment and the Rule of law should guide individual and collective actions to address the four dimensions of FSN at different scales.

This report and its recommendations aim at helping decision-makers, in governments and international organizations, research institutions, the private sector and civil society organizations, design and implement concrete transition pathways towards more SFSs at different scales, from local (farm, community, landscape) to national, regional and global levels.

Summary

Agroecology: transition pathways towards sustainable food systems

1. Agroecology is a dynamic concept that has gained prominence in scientific, agricultural and political discourse in recent years. It is increasingly promoted as being able to contribute to transforming food systems by applying ecological principles to agriculture and ensuring a regenerative use of natural resources and ecosystem services while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced. Agroecology embraces a science, a set of practices and a social movement and has evolved over recent decades to expand in scope from a focus on fields and farms to encompass whole agriculture and food systems. It now represents a transdisciplinary field that includes all the ecological, sociocultural, technological, economic and political dimensions of food systems, from production to consumption.
2. Agroecology is a transdisciplinary science, combining different scientific disciplines to seek solutions to real world problems, working in partnership with multiple stakeholders, considering their local knowledge and cultural values, in a reflective and iterative way that fosters co-learning

among researchers and practitioners, as well as the horizontal spread of knowledge from farmer to farmer or among other actors along the food chain. Initially the science was focused on understanding field-level farming practices that use few external inputs but high agrobiodiversity, emphasize recycling and maintenance of soil and animal health, including managing interactions among components and economic diversification. The focus has since expanded to include landscape-scale processes, encompassing landscape ecology and, more recently, social science and political ecology related to the development of equitable and sustainable food systems.

3. Agroecological practices harness, maintain and enhance biological and ecological processes in agricultural production, in order to reduce the use of purchased inputs that include fossil fuels and agrochemicals and to create more diverse, resilient and productive agroecosystems. Agroecological farming systems value, *inter alia*: diversification; mixed cultivation; intercropping; cultivar mixtures; habitat management techniques for crop-associated biodiversity; biological pest control; improvement of soil structure and health; biological nitrogen fixation; and recycling of nutrients, energy and waste.

4. There is no definitive set of practices that could be labelled as agroecological, nor clear, consensual boundaries between what is agroecological and what is not. On the contrary, agricultural practices can be classified along a spectrum and qualified as more or less agroecological, depending on the extent to which agroecological principles are locally applied. In practice this comes down to the extent to which: (i) they rely on ecological processes as opposed to purchased inputs; (ii) they are equitable, environmentally friendly, locally adapted and controlled; and (iii) they adopt a systems approach embracing management of interactions among components, rather than focusing only on specific technologies.

5. Social movements associated with agroecology have often arisen in response to agrarian crises and operated together with broader efforts to initiate widespread change to agriculture and food systems. Agroecology has become the overarching political framework under which many social movements and peasant organizations around the world assert their collective rights and advocate for a diversity of locally adapted agriculture and food systems mainly practised by small-scale food producers. Social movements highlight the need for a strong connection to be made between agroecology, the right to food and food sovereignty. They position agroecology as a political struggle, requiring people to challenge and transform the structures of power in society.

6. There have been many attempts to set out principles of agroecology in the scientific literature. This report suggests a concise and consolidated set of 13 agroecological principles related to: recycling; reducing the use of inputs; soil health; animal health and welfare; biodiversity; synergy (managing interactions); economic diversification; co-creation of knowledge (embracing local knowledge and global science); social values and diets; fairness; connectivity; land and natural resource governance; and participation.

7. An agroecological approach to SFSs is defined as one that favours the use of natural processes, limits the use of external inputs, promotes closed cycles with minimal negative externalities and stresses the importance of local knowledge and participatory processes that develop knowledge and practice through experience, as well as scientific methods, and the need to address social inequalities. This has profound implications for how research, education and extension are organized. An agroecological approach to SFSs recognizes that agri-food systems are coupled with social-ecological systems from the production of food to its consumption with all that goes on in between. It involves agroecological science, agroecological practices and an agroecological social movement, as well as their holistic integration, to address FSN.

8. Agroecology is practised and promoted in various locally adapted forms by many farmers and other food system actors around the world. Their experience underpins a continuing debate about the extent to which agroecological approaches can contribute to design SFSs that achieve FSN at all levels. This debate revolves around the following three critical issues. (i) How much food needs to be produced to achieve FSN; centred on whether FSN is mainly a problem of availability or more an issue of access and utilization? (ii) Could agroecological farming systems produce enough food to meet global demand for food? (iii) How to measure the performance of food systems, taking into account the many environmental and social externalities that have often been neglected in past assessments of agriculture and food systems?

9. There is no single, consensual definition of agroecology shared by all the actors involved, nor agreement on all the aspects embedded in this concept. While this makes it hard to pin down

exactly what is agroecology and what is not, it also provides a flexibility that allows agroecological approaches to develop in locally adapted ways. There can be tensions and diverging views between science and social movements around whether social and political dimensions are critical for agroecology to be effectively transformative and whether these dimensions should be distinguished from agroecological practices and techniques focused at field and farm scales. There are emerging efforts to define which agricultural practices are agroecological or not, allied to discussions about convergence or divergence with organic agriculture, which is more prescriptive, and about the development and use of certification schemes.

10. There has been much less investment in research on agroecological approaches than on other innovative approaches, resulting in significant knowledge gaps including on: relative yields and performance of agroecological practices compared to other alternatives across contexts; how to link agroecology to public policy; the economic and social impacts of adopting agroecological approaches; the extent to which agroecological practices increase resilience in the face of climate change; and how to support transitions to agroecological food systems, including overcoming lock-ins and addressing risks that may prevent them.

11. Five phases have been identified by Gliessman (2007) in making agroecological transitions towards more sustainable food systems. The first three operate at the agroecosystem level and involve: (i) increasing input use efficiency; (ii) substituting conventional inputs and practices with agroecological alternatives; and iii) redesigning the agroecosystem on the basis of a new set of ecological processes. The remaining two steps operate across the whole food system and involve: (iv) re-establishing a more direct connection between producers and consumers; and (v) building a new global food system based on participation, localness, fairness and justice. While the first two steps are incremental, the latter three are more transformative.

Innovation for sustainable food systems

12. **Innovation** in this report refers to the process by which individuals, communities or organizations generate changes in the design, production or recycling of goods and services, as well as changes in the surrounding institutional environment. Innovation also refers to the changes generated by this process. Innovation includes changes in practices, norms, markets and institutional arrangements, which may foster new networks of food production, processing, distribution and consumption that may challenge the *status quo*.

13. **Innovation systems** are the networks of organizations, communities, enterprises and individuals within which changes are generated and spread. **Innovation platforms** are initiatives or efforts bringing together diverse stakeholders to create space for co-learning and collective action that support transitions towards SFSs for FSN.

14. Conventional views of innovation in agriculture have often focused on the introduction and spread of adoption of new technologies. Recently greater emphasis has been placed on promoting: (i) inclusive and participatory forms of innovation governance; (ii) information and knowledge co-production and sharing among communities and networks; and (iii) responsible innovation that steers innovation towards social issues.

15. Innovations in agriculture and food systems are distinct from those in many other sectors, because ecological processes and social interactions have a central role. Therefore, adaptation to local environmental and social conditions is critical in the innovation process. Food producers have intimate knowledge of the agroecosystems within which they act, so that agri-food innovation systems may draw heavily on local knowledge and practices.

16. This report describes several innovative approaches to SFSs and clusters them in two main categories: (i) **sustainable intensification of production systems and related approaches** (including climate-smart agriculture, nutrition-sensitive agriculture and sustainable food value chains) that generally involve incremental transitions towards SFSs; and (ii) **agroecological and related approaches** (including organic agriculture, agroforestry and permaculture) that some stakeholders consider to be more transformative. While the former category starts from a premise that, to address future challenges, productivity per unit of land needs to increase in a sustainable manner, which is what is meant by sustainable intensification, the latter emphasizes reducing inputs and fostering diversity alongside social and political transformation focused on improving ecological and human health and addressing issues of equity and governance.

17. The report highlights the points of convergence and divergence existing among these different innovative approaches, building its comparative analysis upon the following nine characteristics: (i) regenerative production, recycling and efficiency; (ii) biodiversity, synergy and integration; (iii) economic diversification versus specialization; (iv) climate change adaptation and mitigation; (v) knowledge generation and dissemination; (vi) equity; (vii) labour versus capital intensification; (viii) connectivity versus globalisation; and (ix) governance and participation. Each characteristic is described in a dynamic way, as a spectrum of various possible positions lying between two opposite poles.

18. Sustainable intensification and related approaches are viewed as contributing most strongly to FSN by improving availability and stability, as well as to the operational principles of resource efficiency and resilience. In contrast, agroecological and related approaches are viewed as contributing substantively to the access and utilization dimensions of FSN and to the third principle of social equity/responsibility. Participation and empowerment are central in these approaches.

19. This analysis identified the potential utility of adding ecological footprint as a fourth operational principle for SFSs to adequately capture how consumption patterns affect what is produced and how ecologically degradative and regenerative practices have impacts beyond those that occur through resource efficiency, since resource-efficient practices can still be degradative. Ecological footprint expresses the impact of food consumed by a defined group of people measured in terms of the area of biologically productive land and water required for production and to assimilate the wastes generated. It contributes to assessing sustainability; its trend over time indicates to what extent transitions towards SFSs are occurring.

20. The comparative analysis of approaches also identified a possible opportunity to consider adding the emerging concept of “agency” as a fifth pillar of FSN to capture the importance of people’s participation in decision-making around how the food they eat is produced, processed, stored, transported and sold. “Agency” refers to the capacity of individuals or communities to define their desired food systems and nutritional outcomes, and to take action and make strategic life choices in securing them.

Diverging perspectives on how to achieve food system transformation

21. The HLPE identifies in this report five main groups of interacting factors that may act as barriers to innovation: (i) governance factors; (ii) economic factors; (iii) knowledge factors; (iv) social and cultural factors; and (v) resource factors.

22. While there is a global consensus emerging around the transformation needed in agriculture and food systems, there is no agreement on which innovative approaches should be promoted to foster this transformation. Six controversial issues are presented in this report, each summarized in the six following paragraphs of this summary. They illustrate and highlight key differences among innovative approaches that affect both the action of drivers on innovation and potential barriers to transitions. They relate to: (i) the size of agricultural enterprises; (ii) the deployment of modern biotechnologies; (iii) the deployment of digital technologies; (iv) the use of synthetic fertilizers; (v) biofortification; and (vi) biodiversity conservation strategies. Characterizing these controversial issues is fundamental to understand the possible blockages and make relevant recommendations on how best to address them.

23. There is an increasing recognition that economies of scale in agriculture are context-dependent and vary with the extent to which environmental and social externalities are factored into performance measurement metrics. Smaller farms may often be labour-intensive, as opposed to capital-intensive, and while overall yields (assessed through the land equivalent ratio) may be high for polycultures, the yield of a single staple crop may often be lower than in large-scale monocultures. Economies of scale, which may exist within current regulatory frameworks, subsidies and avoided costs of externalities (impact of pollution, lowering soil carbon or providing less rural labour), would require interventions to avoid market failures resulting in continued degradation of agroecosystems associated with the increased scale of operation. While diversity has sometimes been associated with smaller farm sizes, large-scale farming operations are also starting to experiment with transitions towards more agroecological practices, through diversification that enhances both performance and resilience. So, the issues that are discussed in relation to farm size actually revolve around diversification, which is applicable at multiple scales with supportive public policies, research and civil society initiatives.

24. Despite substantial uptake of gene modification (GM) technology, debates continue to be polarized with public concerns about safety, environmental impacts, concentration of power within food systems and the ethics of gene modification. Some people consider that the uncertainties linked to modern biotechnologies may be addressed through research on a case-by-case basis. However, most agroecological proponents do not consider modern biotechnologies as part of a transition towards SFSs because, as presently constituted, there are conflicts with core agroecological principles associated with ecology, democratic governance and sociocultural diversity. Recent calls for a global observatory for gene editing propose increased scrutiny, dialogue and deliberation on the use of biotechnologies. On a global scale, modern biotechnologies are *de facto* part of the transition towards SFSs because they are already a significant component of the agricultural systems of a number of countries. In contrast, in agri-food systems where input-intensive models have not been adopted, solutions may be found that do not necessarily rely on the adoption of biotechnologies used elsewhere. The suggested observatory would help analyse the diversity of situations.

25. Digital technologies, if more widely adopted, could, according to sustainable intensification proponents, contribute to improve the sustainability of food systems. Technology transfer, farmer education and a transdisciplinary approach involving all actors (scientists, farmers, industry, governments) are considered necessary to realize the potential of digital technologies. Proponents of agroecological approaches emphasize a need to focus on democratic governance, agency and knowledge systems, to scrutinize *what* is being attempted through the use of digital technologies, *by whom*, and *what kinds* of future food systems are being fostered through their application. Agroecology proponents are not in opposition to digital technologies but often have concerns about the way they are currently used and controlled. Public policies aimed at improving the access to digital agricultural technologies could be used in better connecting producers and consumers as well as facilitating citizen science.

26. Use of synthetic fertilizers has been a major source of yield gains in agriculture as well as of environmental pollution resulting both from their manufacture and their use in farming. The economic cost of environmental pollution in contexts where large quantities of fertilizer have been applied have often outweighed the economic value of increased agricultural yield. Use of fertilizer, often associated with pesticides and modern crop varieties, has been and still is subsidized in many contexts. Where inorganic fertilizer is used without organic additions, soil structure and biotic function may decline, contributing to land degradation. Small-scale farmers using a lot of purchased inputs have sometimes become vulnerable to debt, especially where climate change exacerbates the risk of crop failure, while the use of fertilizer has been the foundation for other farmers to exit poverty. There has been much progress recently in more efficient use of fertilizer through microdosing and integrated soil fertility management that combines the use of organic and inorganic amendments. The viability of different strategies for maintaining soil fertility in high-yielding agricultural practices is highly context-dependent, in relation to soil type, the nature of the farming system and what sources of fertilizer are locally available. While nitrogen can be biologically fixed by incorporating legumes in cropping practices and nutrient cycling can be enhanced through the use of agroecological practices, replacing the phosphorus which is removed with crop products is more challenging, especially if there are no locally available rock phosphate resources. Knowledge gaps have been observed on locally appropriate strategies for maintaining soil fertility that are environmentally sustainable at the same time as being economically viable for farmers.

27. Growing a diverse mix of crops is often contrasted with biofortification of staple crops as alternative strategies to address nutritional deficiencies. Biofortification involves increasing the nutritional value of crops through conventional plant breeding (e.g. beta-carotene rich orange-fleshed sweet potato; iron-rich beans, rice and pearl millet; and quality protein maize), transgenic methods (e.g. betacarotene-rich “golden” rice) or agronomic practices (e.g. zinc-rich wheat). Biofortification has resulted in improved nutritional outcomes in specific contexts but there is less information about its impacts on other dimensions of FSN. Diversified production has been positively correlated with improved FSN through both direct consumption and sale of products increasing income that then confers greater FSN. Critics suggest that biofortification may contribute to reliance on single food solutions that may be an inherently risky and “less-resilient” approach than to maintain a diversity of crops and the knowledge required to grow, process, prepare and eat them. The two strategies can be integrated with producers and consumers being offered informed choices about adopting biofortified crops, diversified production or both.

28. There is a long-standing debate about the extent to which conserving biodiversity within agricultural landscapes (land sharing) can contribute to meeting conservation goals as opposed to maximizing the land area available only for conservation purposes through maximizing agricultural production on the land area devoted to it (land sparing). Agroecological approaches to FSN challenge the assumptions underlying this apparent dichotomy. First, in terms of whether conservation friendly agricultural practices are necessarily low-yielding and, second, the extent to which the impacts on biodiversity of chemical-intensive agriculture are confined to the areas where it is practised. There is growing consensus that the overall impact of agriculture on insect and other biodiversity is reaching alarming proportions that exceed planetary boundaries.

29. Looking across the six controversial issues, it is possible to identify knowledge gaps around specific metrics of food system performance required to guide food system transitions and to clarify critical decisions that need to be made, including opportunities for reformulating the controversial issues towards the design of solutions on the one hand, or political choices among divergent views on the other. It is clear that market forces, left to themselves, are unlikely to result in transitions towards SFSs. This is because there are many externalities associated with production, processing and distribution of food that are not priced and because the power exerted from the increasingly concentrated agri-food input and retail sector often works against addressing these externalities. People can exert pressure to close market failures through their purchasing decisions, but this is only possible if there are: (i) affordable products produced sustainably; (ii) products that are labelled so that consumers can exert their choices; and (iii) the information about how food has been produced is both available and trusted. There are moves within the private sector to upgrade value chains and establish and participate in certification schemes that may be either centrally run or more participatory in nature. Under appropriate circumstances, these may guarantee sustainability and equity along food chains and can contribute to enabling consumers to choose sustainably produced food facilitated by an appropriate food environment (HLPE, 2017). Government policy, regulation and moves towards true pricing aim at internalizing all ecological and social effects of production in the price of food, enabling markets to function in ways that would foster transitions towards SFSs. This requires harnessing connections between transdisciplinary science that can understand how social-ecological systems work, and social movements and civil society organizations that can trigger and sustain the change necessary to foster transitions towards SFSs.

Design of institutional environments that support transitions towards SFSs

30. A considerable inertia, manifest in public policies, corporate structures, education systems, consumer habits and investment in research, favours the currently dominant model of agriculture and food systems, representing a series of lock-ins. In the dominant model, environmental and social externalities are not properly considered and, therefore, not appropriately factored into decisions influencing the development of food systems. To overcome this inertia and challenge the status quo, it is imperative to create a level playing field on which different approaches can be equitably compared. This requires redirection of investments and efforts to design and implement innovative approaches, including agroecological approaches, that provide concrete alternatives to the dominant model and open transition pathways towards SFSs.

31. Designing supportive public policies to foster transitions towards SFSs may include shifting public support towards more diversified farming systems. Given that many smallholder farmers are vulnerable to food insecurity and malnutrition, encouraging them, through appropriate public support (HLPE, 2013a), to use agroecological methods would have a double impact, addressing both FSN and transitions to SFSs simultaneously. Public support measures that enable producers, regardless of their scale of operation, to make greater use of sustainable food production methods could include removing subsidies for synthetic inputs while giving incentives for sustainable food production methods, and for managing multifunctional landscapes including wild species. A substantial barrier to premium pricing for sustainably produced food is that market prices usually do not include the cost of negative externalities of production, nor reward the positive benefits of systems with positive ecological impacts.

32. Key changes in agriculture and food policies that could contribute to transitions towards SFSs for FSN include: putting greater emphasis on health and nutritional benefits; implementation of true cost accounting; focusing effort on areas where evidence suggests the fastest progress can be made in achieving FSN outcomes, such as education, particularly girl’s education; measures to support the creation of decent and safe forms of employment, particularly for young people, but

also for marginalized groups such as farmworkers and migrants; and putting greater emphasis on processing, distribution, market and consumption aspects of food systems including creating participatory guarantee schemes that build stronger socio-economic relationships between producers and consumers.

33. Barriers to diversification of food systems include intellectual property protection and seed legislation, which might need significant change, depending on the national legal context. Seed legislation that supports the exchange and access to seeds from genetically heterogeneous varieties, including traditional crops, is an important component of this. Other barriers include large-scale land acquisitions that result in loss of access to natural resources for local populations and can worsen the FSN status of small-scale producers and the rural poor. Support for customary land rights for small-scale producers, and respect for the Voluntary Guidelines on Responsible Governance of Tenure for Land, Fisheries and Forest, adopted by CFS in 2012, would strengthen the ability of small-scale food producers and the rural poor to implement agroecological practices thanks to improved access to land, forests and water resources.

34. Comprehensive performance metrics, covering all the impacts of agriculture and food systems, are a key requirement for rational decision-making. The relevance of metrics is scale-specific. The performance of individual practices needs to be measured in relation to their purposes. This may involve measuring quantities like crop yield, soil organic carbon content, or income from sale of products with consideration of the variability of performance across contexts. Practices are integrated within farms or livelihood systems, making the total factor productivity of farm enterprises or smallholder livelihoods a key integrated metric at household level. At landscape scale, the concept of land equivalent ratio can be applied to ecosystem services to derive a multifunctionality metric that sums the effects of agriculture on all provisioning, regulating and cultural ecosystem services weighted by their relative societal value, in the place they are provided. Operationalizing such a metric requires development of policy processes that can be implemented at local landscape scales (10–1 000 km^2) at which many ecosystem services first manifest, and at which social capital among land users is required to manage territorial resources. For whole food systems, an ecological footprint represents an integrated metric that takes into account both what people consume and how it is produced, processed, transported and used.

35. The utility of ecological footprint in developing national and international policy has been recognized, although refinement of accounting methods is required to fully capture the concept of biocapacity, taking account of degradative as opposed to regenerative agricultural practices, and trade-offs between different ecosystem services. A key reason for distinguishing ecological footprint from resource efficiency, as operational principles, lies at the heart of the differences between agroecological and sustainable intensification approaches to transitions to SFS, because it is possible to have high resource use efficiency at the same time as having a negative ecological footprint. A key practical requirement for sustainable agricultural production is the use of practices that are regenerative rather than degradative. In whole food systems, diet, resource use and waste along food chains all become important, together with appropriate metrics that measure ecological, social as well as economic performance of alternative options.

36. The reconfiguration of the relationship between formal scientific research and the local knowledge and experience of farmers, rural and urban communities and other actors along food value chains, many of whom are in the private sector, has proved to be useful. Taking steps to achieve greater integration of local and scientific knowledge, and of knowledge along food chains, has two key dimensions. Firstly, investment in strengthening capacity around supporting local innovation. Secondly, fundamental reconfiguration to address knowledge gaps and span boundaries between social movements, operating with strongly held convictions that motivate action towards more sustainable agriculture and food systems at grassroots level, and formal research systems that are sometimes perceived to be antagonistic rather than supportive of the knowledge base on which decisions can be made.

37. Investments in agriculture and food systems research and development (R&D) have evidenced impact. Between 2000 and 2009, global expenditure on agricultural R&D increased by 3.1 percent a year on average (only 2.3 percent a year in low-income countries), from USD 25.0 billion to USD 33.6 billion, almost half of this increase being spent in China and India. FAO estimates that three-quarters of the investments in agricultural research and extension are realized in G20 nations. Global R&D investments are focused mainly on a few major staple crops, mostly cereals, while other nutritious crops (such as pulses, fruits and vegetables, as well

as the so-called orphan crops) are often neglected. The private sector also heavily invests in food system R&D and is increasingly interested in value chain upgrading to ensure environmentally and socially sustainable supply chains leading to co-investment with public funds around key sustainability issues including adaptation to climate change.

38. The involvement of the next generation of food producers in transitions to SFSs is too low. The lack of immediate benefits, poor agricultural support services, lack of information about appropriate technologies and practices, land degradation and poor infrastructure are some of the factors identified as disincentives for young people to be involved in agriculture. Recognizing the particular constraints and challenges that young people face in trying to establish diversified farming systems and food enterprises, including access to land, credit and information, is important. Digital technologies present new opportunities to engage young people.

39. Agroecology initiatives that advocate for women's formal rights are essential. These ensure land access, more equitable family and community relationships, and reorientation of institutions and organizations to explicitly address gender inequality. This latter inequality is a key barrier to transitions to SFS in many contexts. There is increasing momentum in the policy arena for gender transformative actions that address gender inequality in agriculture and food systems. These actions aim to challenge the underlying causes of gender inequality, such as norms, gender relations in households and society, and institutional structures that perpetuate discrimination and imbalances, rather than merely addressing its symptoms. They seek to achieve more equitable involvement of women and girls in decision-making, control of resources and control of their own labour and destiny. A sufficient proportion of the population in a community must be involved to ensure that the needed structural changes will be lasting and pervasive. Addressing gender inequality requires recognition of: (i) women's central roles in agriculture and food systems; and (ii) the often-high labour demands in holistic agricultural management systems, making greater income equality for those providing important labour.

40. Public education and awareness raising that use democratic, grassroots approaches are key elements for transforming agriculture and food systems. They can be combined with active involvement of diverse civil society organizations and private sector initiatives in governance forums at different scales. This results in individual citizens and civil society organizations having greater agency in respect of how their food is produced, processed, transported and sold. Global institutions that play a key role, such as global trade organizations and international financial institutions, need to be transparent and democratically accountable, particularly challenging in relation to inclusion of marginalized rural and urban, low-income communities.

Conclusion

41. The CFS can serve as a model of inclusive civil society and private sector involvement and a starting point for implementing transitions towards FSN. Strategies and planning for implementing agroecological approaches at different scales (local, territorial, national, regional and global) can help achieve this fundamental transformation of food systems by: setting long-term goals; ensuring policy coherence across sectors (agriculture, trade, health, gender, education, energy and environment); and involving all relevant actors through consultative multi-stakeholder processes.

Recommendations

There is no “one-size-fits-all” solution to realizing the transformation of food systems globally required to achieve food security and nutrition (FSN). It will require supporting a diversity of transitions from different starting points, along different pathways, adapted to the local conditions and challenges faced in different places by different people. The following recommendations, distilled from the deliberations of this report, aim to help decision-makers develop concrete actions that will encourage and support the innovation required at local, territorial, national, regional and global scales to follow appropriate transition pathways towards sustainable food systems (SFSs) that enhance FSN.

1. AGROECOLOGICAL AND OTHER INNOVATIVE APPROACHES IN AN INTEGRATED WAY TO FOSTER TRANSFORMATION OF FOOD SYSTEMS

All stakeholders involved in food systems (including: States, local authorities, intergovernmental organizations (IGOs), civil society and the private sector, research and academic institutions) should learn from agroecological and other innovative approaches concrete ways to foster transformation of food systems by improving resource efficiency, strengthening resilience and securing social equity/responsibility.

In particular, they should:

a) take into account and value the diversity of food systems and their contexts across scales when developing transition pathways to SFSs;

b) use relevant performance metrics for food systems that consider all environmental, social and economic impacts of food production and consumption;

c) recognize the importance of improving the ecological footprint[1] of food systems as an operational principle for transitioning to SFSs, and thereby encourage appropriate consumption alongside agricultural and other food production practices that maintain or enhance, rather than deplete, natural capital;

d) encourage integration of transdisciplinary science and local (including indigenous) knowledge in participatory innovation processes that transform food systems.

Specifically, CFS should:

e) consider the emerging importance of the concept of ‘agency’ and the opportunity to add it as a fifth pillar of FSN with the view to progress towards the realization of the right to adequate food.

2. SUPPORT TRANSITIONS TO DIVERSIFIED AND RESILIENT FOOD SYSTEMS

States and IGOs should:

a) Support diversified and resilient production systems, including mixed livestock, fish, cropping and agroforestry, that preserve and enhance biodiversity, as well as the natural resource base, exploring:
   i. **redirecting** subsidies and incentives that at present benefit unsustainable practices, to support transition towards SFSs;
   ii. **supporting** use of participatory and inclusive territorial management planning to identify and foster locally sustainable practices and to protect common natural resources at different levels (landscape and community, national, regional and global);
   iii. **building** adaptation of international agreements and national regulations on genetic resources and intellectual property to better take into account farmers’ access to diverse, traditional and locally adapted genetic resources, as well as farmer-to-farmer seed exchange;

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[1] Ecological footprint puts the food consumed by a given population in relation to the bioavailable land and water resources required to produce it and absorb its associated waste. It can be improved by reducing consumption and waste, as well as through more efficient production.

    iv. **strengthening** the regulations on the use of chemicals harmful for human health and the environment in agriculture and food systems, promoting alternatives to their use and rewarding practices that produce without them;
    v. **building** social capital and inclusive public bodies at territorial landscape scale (10–1 000 km^2) so that policy processes can be implemented at a scale where the provision of, and the trade-offs among, key ecosystem services (provisioning, regulating, supporting and cultural) can be managed.

b) **Promote** healthy and diversified diets as an avenue to support transitions towards more sustainable, diversified and resilient food systems through:
    i. education and awareness;
    ii. appropriate food labelling and certification;
    iii. support for low-income consumers and the use of public procurement policies, including school feeding programmes.

c) **Support** food value chain innovation platforms, incubators and aggregation mechanisms[2] in which private sector actors, as well as public bodies, invest in and reward sustainable food producers and the production of public goods, exploring:
    i. **supporting** the development of local and regional markets, processing hubs and transportation infrastructures that provide greater processing and handling capacities for fresh products from small and medium-sized farmers adopting agroecological and other innovative approaches and improve their access to local food markets;
    ii. **encouraging incentives** for young entrepreneurs, women and community-led enterprises[3] that capture and retain value locally, recognizing and addressing their specific constraints and needs;
    iii. **harnessing** the use of recent developments in digital technologies to strengthen the links between food producers and consumers including through brokering sustainable finance initiatives and market incentives;
    iv. **adapting support** to encourage local food producers, food enterprises and communities to build recycling systems by supporting the reuse of animal waste, crop residue and food processing waste in forms such as animal feed, compost, biogas and mulch.

3. STRENGTHEN SUPPORT FOR RESEARCH AND RECONFIGURE KNOWLEDGE GENERATION AND SHARING TO FOSTER CO-LEARNING

States and IGOs, in collaboration with academic institutions, civil society and the private sector should:

a) increase investments in public and private research and development, and in national and international research systems to support programmes in agroecological and other innovative approaches, including to improve technologies;
b) develop and support transdisciplinary research conducted through innovation platforms that foster co-learning between practitioners and researchers, and horizontal dissemination of experience among practitioners (e.g. farmer-to-farmer networks, communities of practice and agroecological lighthouses);
c) encourage explicit coverage of "transitions to SFSs" in school and university curricula, integrating hands-on, experiential learning;
d) ensure that training programmes for agricultural extension and public health workers are promoting learning processes and the use of adequate technologies as well as a better

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[2] Aggregation mechanisms refer to ways of bulking outputs or inputs to improve market access as sometimes achieved through cooperatives.

[3] Community-led enterprises engage directly with local people, with a lead partner that is a charity, social enterprise, not-for-profit or member (cooperative) organization and has a sustainable business plan aiming at viability beyond grants or public funding.

understanding of the role of agroecological practices for nutrition and human, animal and environmental health;

e) establish and develop effective technology transfer mechanisms to enhance the adoption of technologies in agroecological and other innovative approaches by farmers/producers and other stakeholders involved in various stages of value chains of food commodities;

f) address power imbalances and conflicts of interest in relation to the generation, validation and communication of knowledge about food production and processing, by valuing different sources of knowledge and bridging gaps between knowledge generated and transmitted through social movements on the one hand, and the scientific sector on the other.

4. STRENGTHEN AGENCY[4] AND STAKEHOLDER ENGAGEMENT, EMPOWER VULNERABLE AND MARGINALIZED GROUPS AND ADDRESS POWER INEQUALITIES IN FOOD SYSTEMS

States, IGOs and, as appropriate, local authorities should:

a) develop strategies to promote transitions towards SFS setting long-term goals at national and regional levels, ensuring policy coherence across sectors at different levels, bringing together public administrations responsible for, and other relevant stakeholders involved in, agriculture, forestry, trade, health, gender, education, energy and environment;

b) explore ways for trade agreements and rules to better support transitions towards more sustainable agriculture and food systems;

c) support inclusive and democratic decision-making mechanisms at all levels in food systems and take specific measures to ensure the participation of marginalized and vulnerable groups[5] most at risk of food insecurity and malnutrition;

d) in order to favour agroecology and other innovative approaches towards SFSs, ensure legal protection of customary land and natural resources access and tenure rights for small-scale food producers and food-insecure people (small farmers, pastoralists, fisherfolk, forest-dependent people, indigenous peoples) through formal instruments consistent with international legal frameworks,[6] and through national regulation of large-scale land acquisitions;

e) recognize gender equity as a key driver of agroecology and other innovative approaches and support gender transformative policies, programmes and actions that challenge the underlying causes of gender inequality within food systems with respect to norms, relationships and institutional structures, in particular by ensuring that laws and policies improve gender equality and address gender-based violence;

f) strengthen linkages between urban communities and food production systems to favour transitions towards SFSs, specifically by including consumer cooperatives and multi-stakeholder platforms focused on local and regional markets, and increasing investment in food rescue for re-distribution of food to vulnerable people;

g) strengthen food producers’ and consumers’ associations, organizations and cooperatives that build capacities, create and exchange knowledge with a view to facilitate the adoption of agroecological and other innovative approaches that foster transitions towards SFSs.

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[4] “Agency” refers to the capacity of individuals or communities to define their desired food systems and nutritional outcomes, and to take action and make strategic life choices in securing them.

[5] The HLPE (2017) distinguished the vulnerable people with specific nutrient requirements (such as young children, adolescent girls, pregnant and lactating women, the elderly and ill people), and the marginalized people with less control over their diets (such as the urban and rural poor, as well as some indigenous peoples).

[6] For example: UN Declaration on the Rights of Indigenous Peoples; CFS Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT); Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW).

5. ESTABLISH AND USE COMPREHENSIVE PERFORMANCE MEASUREMENT AND MONITORING FRAMEWORKS FOR FOOD SYSTEMS

States and IGOs, in collaboration with academic institutions, civil society and the private sector, should**:**

a) develop practical, scientifically grounded and comprehensive performance metrics and indicators of agriculture and food systems as a basis for assessment, policy implementation and investment decisions, including total factor productivity of livelihoods, land equivalent ratio multifunctionality of landscapes and ecological footprint of food systems, as well as impacts on beneficial organisms, dietary diversity and nutritional outcomes, women's empowerment, income stability and employment conditions, as appropriate;

b) redirect public and private investment and specifically agricultural subsidies to support farms based on the comprehensive performance metrics set out in 5a that assess their sustainability and impact on FSN;

c) recognize the importance of true cost accounting for negative as well as positive externalities in food systems and take steps to effectively implement it where appropriate;

d) recognize that, providing farmers/producers and other stakeholders comply with public policy and safety standards, participatory guarantee systems are a valid means to certify organic, ecological and agroecological producers for local and domestic markets, which are often the most feasible for low-income, small-scale producers to access;

e) promote rigorous, transparent and inclusive assessments of modern biotechnology, including support for a global observatory for gene editing;

f) undertake holistic assessments of positive and negative employment and labour characteristics in agriculture to underpin policies and regulations that favour transitions towards SFS, while ensuring decent conditions for farm labour and strengthening the health of farm and other food system workers.

FAO should:

g) encourage data collection at national level, documentation of lessons learned and information sharing at all levels, to facilitate the adoption of agroecological and other innovative approaches and foster transitions towards SFSs;

h) in collaboration with member countries, assess and document the contribution of agroecological and other innovative approaches to food security and nutrition at national and global levels.

CFS should:

i) establish transparent, accountable and inclusive mechanisms to monitor if and how these recommendations are being implemented using clear metrics within a specified timeframe;

j) raise awareness of the importance of the contribution of agroecological and other innovative approaches to achieving most of the 2030 Sustainable Development Goals and to advancing the Koronivia Joint Work on Agriculture (KJWA) at national level and consequently at regional and global levels.

INTRODUCTION

Context and objective

With 821 million people still hungry (FAO *et al.*, 2018), it is clear that the global agriculture and food systems are not meeting the world's demand for food. This tension is likely to be exacerbated as food systems will continue to face multi-dimensional, complex and mounting challenges including continued population growth, urbanization, climate change and increased pressure on natural resources (land, water, biodiversity) and ecosystem functions (Willet *et al.*, 2019). While world food production measured in calories has generally risen faster than population, current food systems result in different forms of malnutrition (undernutrition, micronutrient deficiencies, overweight and obesity) now affecting all countries, whether low-, middle- or high-income. These different forms of malnutrition can co-exist within the same country or community, and even within the same household or individual (HLPE, 2017b). Current food systems also affect food security and nutrition (FSN) indirectly through their economic and health impacts, including: low income and difficult livelihoods for many food producers that are often net food buyers; fragile economic viability for many small and medium-sized food enterprises; and precarious and difficult working conditions for many farm and food workers (HLPE, 2016, 2017b).

At the same time, there are growing concerns around the political dimensions of food systems, including: power imbalances and lack of democracy in the governance of food systems; lack of transparency and accountability; issues around access to and control over natural resources, including land, water, energy and genetic resources (HLPE, 2015); and increased concentration of power in the input and retail sectors (IPES, 2016; von Braun and Birner, 2017; HLPE, 2016, 2017).

Food systems are at a crossroads and new directions are needed. The High Level Panel of Experts on Food Security and Nutrition (HLPE), in its previous reports (in particular HLPE 2016, 2017), showed that a profound transformation is required in agriculture and food systems to achieve FSN in its four dimensions (availability, access, utilization and stability) and at all scales (Caron *et al.*, 2018). More sustainable food systems (SFSs) are needed that ensure sufficient food production while also safeguarding human and environmental health as well as socio-economic standards.

There are increasing calls for agroecological and other innovative approaches, seen as very different from a "business as usual" approach to agricultural improvement, to play a greater role in contributing to achieve global FSN (De Schutter, 2010; HLPE, 2015, 2016, 2017a,b). Agroecological approaches are becoming increasingly prominent in debates around FSN because they are framed in terms of both their environmental sustainability and social innovation connecting food production and consumption, with strong support for locally adapted solutions based upon participation of local people and their knowledge.

In this context, in October 2017, the UN Committee on World Food Security (CFS) requested the HLPE to produce a report on *Agroecological approaches and other innovations for sustainable agriculture and food systems that enhance food security and nutrition* to inform its discussions during the 46th CFS Plenary Session in October 2019. The objective of this report is to explore the potential contribution of agroecological and other innovative approaches, practices and technologies to creating SFSs that contribute to FSN.[7] This report and its recommendations aim at helping decision-makers, in the different "spheres of society" (HLPE, 2018), to design and implement concrete transition pathways towards more sustainable food systems at different scales, from local (farm, community, landscape) to national, regional and global.

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[7] See: http://www.fao.org/3/a-mu246e.pdf

Transition pathways and food system transformation

The HLPE adopts in this report a dynamic perspective. Central in this report are the concepts of **transition** and **transformation**.

A **transition** is a change in a system, occurring over a period of time, in a specific location (Marsden, 2013). It is often a *"gradual, pervasive shift from one state or condition to something different"* (Hinrichs, 2014). It includes political, socio-cultural, economic, environmental and technological shifts in values, norms and rules, institutions and practices (Marsden, 2013; Pitt and Jones, 2016). Transitions can – but not necessarily – begin at a small, niche scale, referred to as a "seed of transition", a protected space in which businesses, farmer cooperatives, social movements, local governments or other actors design and experiment with innovative approaches and practices, providing possible alternatives to the dominant paradigm (Wiskerke and Van der Ploeg, eds, 2004; Geels, 2010; Marsden, 2013; Hinrichs, 2014). Such transitions may then foster alternative models of food production, processing, distribution and consumption that can challenge the dominant *socio-technological regime*,[8] get absorbed or marginalized by it (Barbier, 2008; Brunori *et al.*, 2011; Levidow *et al.,* 2014). During a transition period, the dominant economic, environmental, political and technological paradigm, rules, institutions and practices become increasingly incompatible with new expectations (Marsden, 2013). External pressures at different scales, from global (e.g. climate change), to local (e.g. soil erosion), as well as political institutions, private companies, social movements or consumer expectations can push the dominant regime towards transition or create "lock-ins" that reinforce the *status quo* (Smith and Stirling, 2010; Fonte, 2013; Hinrichs, 2014; IPES-Food, 2016).

Many transitions occurring in particular production practices and across the food value chain are required to achieve a **transformation** of food systems involving profound change in what is produced and how it is produced, processed, transported and consumed. More sustainable production and consumption patterns can be reached over time through a dynamic interaction between innovations in food production enterprises, social movement advocacy, policy and cultural change at different scales (Spaargaren *et al.*, 2012; Hinrichs, 2014). A multi-level perspective has been widely used in examining sustainability transitions to consider how unpredictable and dynamic processes and interactions across scales work to foster transformative changes across the whole food system (Geels, 2010; Smith *et al.*, 2010). Both incremental transitions at small scales and more structural changes to institutions and norms at larger scales need to happen in a coordinated and integrated way in order to achieve the transformation of food systems required to achieve FSN globally (Elzen *et al.*, 2017).

In its previous reports, the HLPE (2016, 2017) highlighted the huge diversity of food systems across and within countries. These food systems are situated in different environmental, socio-cultural and economic contexts and face very diverse challenges. Hence, actors in food systems will have to design context-specific and adapted transition pathways towards sustainable food systems (Sinclair and Coe, 2019). As highlighted by the HLPE (2016), context-specific transition pathways should combine technical interventions, investments, and enabling policies and instruments, and involve a variety of actors at different scales. They can be grounded on very different narratives, each of which drives a selection of options.

Beyond this context-specificity, the HLPE (2016) identified three interlinked operational principles for sustainable agricultural development that, applied more broadly, can shape those transition pathways towards SFSs for FSN: (i) **improve resource efficiency**; (ii) **strengthen resilience**; and (iii) **secure social equity/responsibility**. These three operational principles address the need for a rational use of inputs and scarce resources, contending with climate change, and bringing social dimensions more centrally into food systems.

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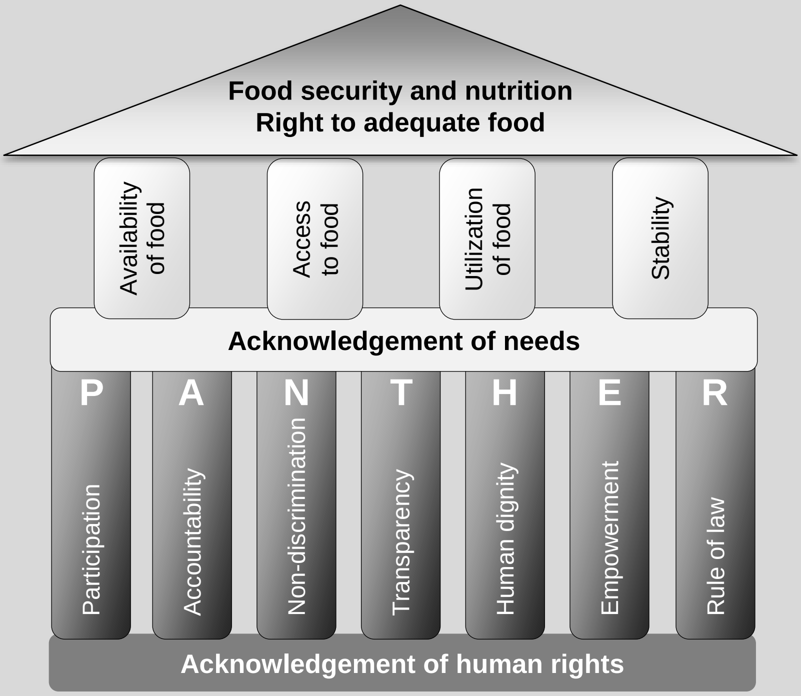
[8] A *socio-technological regime* is the set of norms, rules and institutions that guide the direction of social and technological innovations (adapted from: Possas *et al.,* 1996; Vanloqueren and Baret, 2009).

Box 1 Human rights as a general framework

This report starts from the recognition of **human rights** as the general basis for ensuring SFSs and achieving FSN for all, now and in the future. The International Covenant on Economic, Social and Cultural Rights (UN, 1966), in its Article 11, explicitly recognizes the *"right of everyone to an adequate standard of living for himself and his family, including adequate food, clothing and housing, and to the continuous improvement of living conditions"* as legally binding for all states parties. The UN General Assembly (UNGA, 2014) defines the human right to adequate food as the right of every individual *"alone or in community with others, to have physical and economic access at all times to sufficient, adequate and culturally acceptable food, that is produced and consumed sustainably, preserving access to food for future generations"*.

Figure 1 FSN in a human rights-based framework



Source: adapted from Ekwall and Rosales (2009)

The legal obligations of state parties to *respect, protect* and *fulfil* this right were further refined in General Comment No. 12 of the Committee on Economic, Social and Cultural Rights (UNCESCR, 1999). States are obliged to *respect* the right to adequate food by not taking any measures that prevent access to food. They must *protect* the right to adequate food by ensuring that individuals are not deprived of access to adequate food. Finally, they must *fulfil* (facilitate) this right by engaging pro-actively in activities that strengthen people's access to resources and means to ensure their livelihood, including their FSN. In cases where people are unable to enjoy the right to adequate food, States must *fulfil* (provide) that right directly, including through food aid (UNCESCR, 1999). Historically marginalized and vulnerable groups that are more likely to experience human rights violations, including small-scale food producers, indigenous peoples, poor households, women, children and refugees, are also more likely to experience food insecurity and malnutrition (Quisumbing and Smith, 2007; Ayala and Meier, 2017). The recent UN Declaration on the Rights of Peasants and Other People Working in Rural Areas (UNGA, 2018), which addresses such issues, commits the United Nations and its specialized agencies, funds and programmes, and other intergovernmental organizations, to promote respect for and the full application of the present Declaration, and follow up on its effectiveness.

Under a human rights-based framework, the seven PANTHER principles of Participation, Accountability, Non-discrimination, Transparency, Human dignity, Empowerment and the Rule of law should guide individual and collective actions to address the four dimensions of FSN at different scales and progressively realize the right to adequate food (see **Figure 1**).

Structure of the report

This report comprises four chapters. The first two chapters develop the two central concepts highlighted in the CFS request, namely agroecological (Chapter 1) and innovative approaches (Chapter 2). Chapter 3 analyses controversial issues on how to achieve the needed food system transformation. The intention is not to resolve such controversies, but to clarify their nature and highlight where diverging views and values can bring different perspectives to a common issue. Finally, Chapter 4 explores the design of institutional environments that can encourage transition pathways required to underpin the profound transformation of SFSs that is required to achieve FSN globally.

Box 2 FSN and sustainable food systems

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Conceptually, food security and nutrition overlap, with food security a necessary but not sufficient condition for nutrition security (Jones *et al.*, 2014a). The World Summit on Food Security (WSFS, 2009) stated that "the nutritional dimension is integral to the concept of food security". Building on previous works, the International Bank for Reconstruction and Development and the World Bank (2006) considered that: "Nutrition security exists when food security is combined with a sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members". The expression **"food security and nutrition"** (FSN) is commonly used, including in CFS, as a way to combine the two concepts of food security and nutrition security described above (CFS, 2012).

The four dimensions of food security (availability, access, utilization and stability), and the three main determinants of nutrition security (access to food, care and feeding, and health and sanitation), are now widely recognized (CFS, 2012). Building on FAO (2006), previous HLPE reports (2016, 2017, 2018) the four main pillars of FSN are described as follows.

1. **Availability** of sufficient quantities of food of appropriate quality, supplied through domestic production or imports.
2. **Access** by individuals to adequate resources (entitlements)[9] for acquiring appropriate food for a nutritious diet.[10]
3. **Utilization** of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met.[11]
4. **Stability:** to be food secure, a population, household or individual must have access to adequate food available at all times, as well as the possibility to make appropriate use of it.[12]

For the HLPE (2014) a **food system** "gathers all the elements (e.g. environment, people, inputs, processes, infrastructures and institutions) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes". The HLPE (2014) also defined **sustainable food systems** (SFSs) as food systems that "ensure food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised."

The HLPE (2017b) identified three core constituent elements of food systems: (i). food supply chains; (ii). food environments; and (iii). consumer behaviour. The **food supply chain** comprises all activities that move food from production to consumption (production, storage, distribution, processing, packaging, retailing and marketing[13]), as well as all the actors involved in these activities.

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[9] "Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources)" (FAO, 2006).

[10] This pillar includes physical access to food (proximity) and economic access (affordability) (HLPE, 2017).

[11] This pillar highlights the importance of non-food inputs in FSN and covers some of the abovementioned determinants of nutrition security.

[12] People should not risk losing access to adequate food as a consequence of natural, financial, or social shocks or of cyclical events (e.g. seasonal variability). Stability therefore refers both to availability and access, but also to the stability of the abovementioned non-food inputs.

[13] It also includes waste management and disposal activities linked to these different steps.

The **food environment** refers to the physical, economic, political and socio-cultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food. It serves as an interface between consumers and food systems. It consists of: (i) “food entry points”, i.e. the physical spaces where food is obtained; (ii) the “built environment” – infrastructures that allows consumers to access these spaces; (iii) the personal determinants of food choices (including income, education, values, skills, etc.); and (iv) the political, social and cultural norms that underlie these interactions. The key elements of the food environment that influence food choices, food acceptability and diets are: physical and economic access to food (proximity and affordability); food promotion, advertising and information; and food quality and safety (HLPE, 2017b).

Consumer behaviour reflects all the choices and decisions made by consumers, at the household or individual level, on what food to acquire, store, prepare, cook and eat, and on the allocation of food within the household (including gender repartition and feeding of children). It is influenced not only by personal preferences (determined by different factors including taste, convenience, values, traditions, culture and beliefs) but also largely shaped by the existing food environment.

1 AGROECOLOGY: TRANSITION PATHWAYS TOWARDS SUSTAINABLE FOOD SYSTEMS

Agroecology is a dynamic concept that has gained prominence in scientific, agricultural and political discourse in recent years (IAASTD, 2009; IPES-Food, 2016). During its historical evolution, agroecology has expanded beyond the field, farm and agroecosystem scales to encompass, over the last decade, the whole food system. Agroecological approaches explicitly aim at transforming food and agriculture systems, addressing the root causes of problems and providing holistic and long-term solutions (FAO, 2018a) that consider the complexity of farming systems within their social, economic and ecological contexts (Petersen and Arbenz, 2018). Agroecological approaches are increasingly considered as possible alternatives to the industrial model of agricultural improvement,[14] representing concrete transition pathways towards SFSs that enhance FSN (De Schutter, 2010; HLPE, 2016, 2017a,b).

In September 2014, FAO organized an International Symposium on Agroecology for FSN, followed in 2015 by three regional meetings in Latin America, Africa and Asia (FAO, 2015a,b; 2016a), a further three regional meetings in 2016 in Latin America, China and Europe, and the most recent in 2017 in North Africa (FAO, 2018b). A second International Symposium was convened by FAO in April 2018, the key outcomes of which are documented in Chapter 4 and have informed the development of some of the recommendations in this report.

This chapter begins by describing how the concept of agroecology has emerged from constituent elements of agriculture and ecology to embrace a transdisciplinary science, a set of practices and a social movement. It then presents the definition and development of agroecological principles over time, analysing how these principles contribute to FSN and the achievement of the Sustainable Development Goals (SDGs). Finally, some contested areas in current debates around agroecology and major knowledge gaps are also highlighted.

1.1 Agroecology: a science, a set of practices and a social movement

Multiple definitions of agroecology exist as different institutions and countries adopt definitions that reflect their own concerns and priorities. This report aims at defining and characterizing agroecological approaches for sustainable agriculture and food systems that enhance FSN.

Historically, traditional agricultural systems in many parts of the world could be considered to be agroecological. These include traditional agroforestry, incorporation of organic material into soils, mixed cropping systems with livestock and the use of a wide variety of edible crops (Altieri, 2004a). Dynamic local knowledge systems developed complex approaches to managing pests, diseases and ensuring culturally appropriate, nutrient-rich food supplies (Altieri 2004a; Oteros-Rozas *et al.*, 2013). Modern agroecological science, as a response to the social and ecological impacts of the so-called “industrial” agriculture model, draws on many locally derived concepts and practices, but is also a dynamic and active area of scientific research (Migliorini *et al.*, 2018l; Montalba *et al.*, 2017; Vandermeer and Perfecto, 2013).

In its report on sustainable agricultural development and the role of livestock, the HLPE (2016b)) described agroecology from a scientific and technical perspective as the application of ecological concepts and principles to farming systems, focusing on the interactions between plants, animals, humans and the environment, to foster sustainable agricultural development in order to ensure FSN for all, now and in the future. The report acknowledges that “today’s more transformative visions of agroecology integrate transdisciplinary knowledge, farmers’ practices and social movements while recognizing their mutual dependence”, and calls for looking at a broader conception of the term.

This is in line with agroecological approaches having broadened in recent years, to focus on whole agrifood systems, not only farming systems (Thompson and Scoones, 2009), and to go beyond

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[14] The industrial model of agricultural improvement refers to intensive agricultural systems, dominated by large-scale specialized farms, relying in certain cases heavily on fossil fuel and purchased, non-renewable and synthetic inputs. These systems are criticized by agroecology proponents who point to their negative social, health and environmental impacts (IPES-Food, 2016; HLPE, 2016).

separating scientific and technical dimensions of agroecology from the social and political dimensions, by embracing a transdisciplinary outlook.

The notion of agroecology as the application of ecological principles in agriculture, while apparently simple, hides complex realities because ecology and agriculture are dynamic concepts.

Ecology refers to the branch of biology dealing not only with interactions among organisms and with their environment (Tansley, 1935) but also to social movements concerned with the protection of the environment (Sills, 1974). Although ecological science began as a subdivision of biology, it has more recently emerged as an interdisciplinary field with many different branches, including political ecology (Robbins, 2004), many of which link biological, physical and social sciences.

Agriculture is basically the set of practices through which people produce food (Spedding, 1996). Agriculture, as a concept, is also evolving, with increasing awareness that agriculture is multi-functional (Caron *et al.*, 2008; IAASTD, 2009), and that agricultural production cannot be separated from the other aspects of food systems, such as food supply chains, the food environment and consumption (Jones and Street, eds,1990; HLPE, 2017b).

These trends in ecology and agriculture come together in an emerging transdisciplinary focus on understanding and managing coupled social–ecological systems (Berkes and Folke, eds,1998) in a context of growing concerns about human activities, and agriculture in particular, leading to planetary boundaries being exceeded (Steffen *et al.*, 2015; Campbell, 2017). A key reason that agroecology is gaining traction in the discourse on achieving FSN is because it is perceived to bridge ecological and social dimensions associated with the development of resilient food systems in the face of climate change and other global challenges (Caron *et al.*, 2014).

Agroecology is increasingly seen as a transdisciplinary, participatory and action-oriented approach (Méndez *et al.*, 2013; Gliessman, 2018) that embraces three dimensions: a transdisciplinary **science** (**Definition 1**), a **set of practices** and a **social movement** (Wezel *et al.,* 2009; Wezel and Silva, 2017; Agroecology Europe, 2017) (**Box 3**). These three dimensions of agroecology, their articulation and co-evolution together constitute a holistic approach (e.g. Agroecology Europe, 2017; Gliessman, 2018).

Box 3 Multiple definitions of agroecology

As a **science**, agroecology is: (i) the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions or, in brief, the ecology of the food system (Francis *et al.*, 2003); (ii) the application of ecological concepts and principles to the design and management of sustainable food systems (Gliessman, 2007); and, more recently, (iii) the integration of research, education, action and change that brings sustainability to all parts of the food system: ecological, economic and social (Gliessman, 2018).

Agroecological **practices** aim at improving agroecosystems by harnessing natural processes, creating beneficial biological interactions and synergies among their components (Gliessman, ed, 1990) and using, in the best way, ecological processes and ecosystem services for the development and implementation of practices (Wezel *et al.,* 2014).

As a **social movement**, agroecology is seen as a solution to current challenges such as climate change and malnutrition, contrasting with the so-called “industrial” model and transforming it to build locally relevant food systems that strengthen the economic viability of rural areas based on short marketing chains, and fair and safe food production. It supports diverse forms of smallholder food production and family farming, farmers and rural communities, food sovereignty, local knowledge, social justice, local identity and culture, and indigenous rights for seeds and breeds (Altieri and Toledo, 2011; Rosset *et al.,* 2011; Nyéléni, 2015). This dimension of agroecology as a political movement is becoming increasingly prominent (Gonzalez de Molina, 2013; Toledo and Barrera-Bassols, 2017).

Sources: FAO (2017a), Agroecology Europe (2017).

Definition 1 Transdisciplinary science

Transdisciplinary science transcends disciplinary boundaries and seeks to generate transformative outcomes by having:

(i) a problem focus (research originates from and is contextualized in ”real-world” problems);
(ii) an evolving methodology (the research involves iterative, reflective processes that are responsive to the particular questions, settings and research groupings involved); and
(iii) collaboration (including among transdisciplinary researchers, disciplinary researchers and external actors with interests in the research) (Russel *et al.*, 2008).

This has been interpreted in agroecology to involve integration of different academic disciplines as well as diverse forms of knowledge, including experiential, cultural and spiritual (Méndez *et al.,* 2015).

Transdisciplinary science differs from ”multidisciplinary” science, where people from different disciplines work together, each drawing on their disciplinary knowledge in an additive rather than integrative way, and from ”interdisciplinary” science, where knowledge and methods from different disciplines are integrated, encompassing a synthesis of approaches but not necessarily involving other stakeholders or focus on generating transformative outcomes (Petrie, 1992).

1.1.1 Agroecology as a science

The term “agroecology” appeared for the first time in the scientific literature at the beginning of the twentieth century to designate the application of ecological methods and principles in agricultural ***sciences***, including zoology, agronomy and crop physiology (**Figure 2a**) (Bensin, 1928, 1930; Friederichs, 1930; Klages, 1942; Gliessman, 1997; Dalgaard *et al.,* 2003; Wezel *et al.,* 2009; Wezel and Soldat, 2009). In the 1950s and 1960s, Tischler published several articles on agroecological research, analysing different components (plants, animals, soils, climate) and their interactions, as well as the impact of human management on them. His book was probably the first book entitled *Agroecology* (Tischler, 1965).

The concept of an “agroecosystem”, considered as a domesticated, human-managed ecosystem, was introduced by Odum (1969). Two decades later, agroecology began to move beyond the field and farm scales to embrace whole agroecosystems (Altieri, 1987, 1989; Conway, 1987; Marten, 1988; Wezel *et al.,* 2009; Wezel and Soldat, 2009). Important contributions also came from Mexican scientists emphazing intercultural processes for constructing agroecological knowledge that combines ecological science with local peoples’ knowledge (e.g. Hernández Xolocotzi, 1977).

Building on these reflections, Altieri (1995) defined agroecology as *“the application of ecological concepts and principles to the design and management of sustainable agroecosystems”*. FAO (FAO, 2016d) further refined this definition, stating that: *“Agroecological innovations apply ecological principles - such as recycling, resource use efficiency, reducing external inputs, diversification, integration, soil health and synergies -, for the design of farming systems that strengthen the interactions between plants, animals, humans and the environment for food security and nutrition.”*

In the 2000s, the transdisciplinary nature of agroecological science, combining natural and social sciences, became increasingly important (Wezel *et al.,* 2015). Agroecology was identified as “*an integrated discipline that includes elements from agronomy, ecology, sociology and economics”* (Dalgaard *et al.,* 2003). The focus of agroecological science was broadened to encompass the whole agrifood system (Francis *et al.,* 2003; Doré *et al.*, 2006; Gliessman, 2007; Wezel and David, 2012; Côte *et al.,* eds, 2019) and to cover various topics such as: alternative and local food networks; consumer–producer relationships; social agricultural networks; food markets; and public food procurement. This food systems’ approach also includes the relationships between rural and urban areas, leading to the development of urban agroecology (AS PTA, 2011; Almeida and Biazo, 2017; Renting, 2017; Morales *et al.,* 2018; see also **Box 4**).

Box 4 Urban agriculture

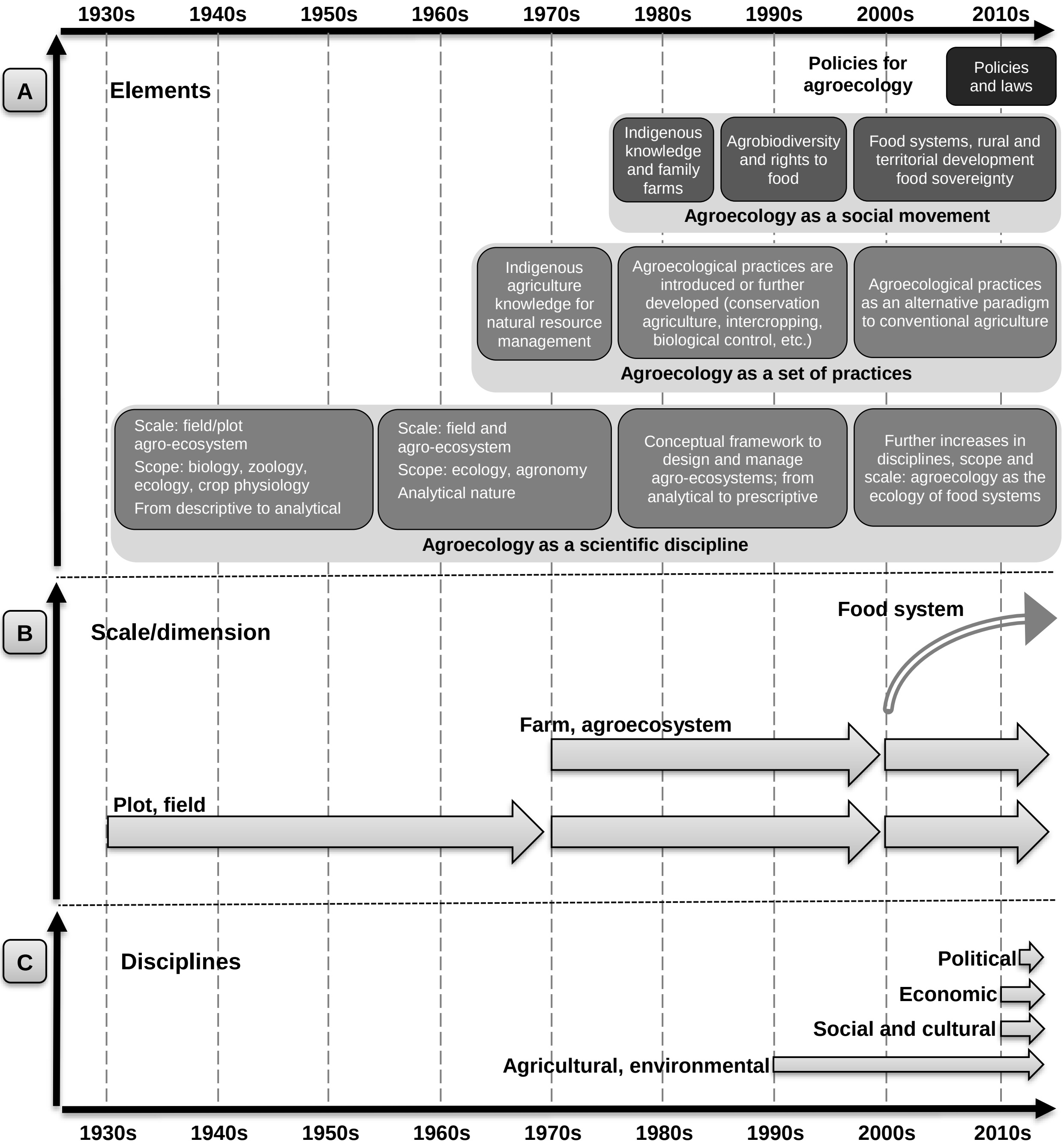
Potentially, urban and peri-urban agriculture (UPA) can play a role in enhancing social and environmental conditions in cities through food security and poverty alleviation, although some people caution that this should not be overemphasized (Zezza and Tasciotti, 2010). In Equatorial Africa, Lee-Smith (2010) found that UPA increases as urban areas expand and that it favours improvement in human health as well as alleviation of hunger and poverty. At a global level, Mok *et al.* (2014) found that UPA has potential to make significant contributions to food security, although more research must be done around issues such as urban sprawl. On the other hand, some authors concluded that UPA has only a limited potential to contribute to urban food security in developing countries given constraints related to access to land, water and financial resources to invest in productive areas in the urban space (Badami and Ramankutty, 2015).

UPA is also valued for the environmental benefits that it might promote, such as biodiversity conservation, reduction of food miles and therefore carbon emissions, and increasing the green areas in urban landscapes. UPA in its many forms – allotment gardens, rooftop gardens, home orchards, urban arborization and community gardens, among others – can contribute to a number of ecosystem services such as pollination, pest control, climate resilience and water regulation (Lin *et al.*, 2015). In fact, locally produced food in urban areas can contribute to create short circuits of commercialization, reducing transportation and also helping to develop direct selling schemes.

Finally, UPA has historically contributed to improve living conditions, increase income and alleviate poverty in cities, strengthening their resilience (Barthel and Isendahl, 2013). In many African countries, where agriculture is the main source of income for the majority of families, UPAs may provide a substantial share of income in addition to promoting a substantial improvement in household diets, contributing to food security and nutrition (Zezza and Tasciotti, 2010). In Mexico City, around 20 percent of all food consumed is produced in urban and peri-urban areas; however, the recognition of the importance of UPA in economic terms and as a source of employment is quite limited. A symbolic dimension of UPAs in Mexico is the pre-Hispanic *chinampas* system (floating gardens) developed by the Aztecs that were greatly reduced following European colonization (Dieleman, 2017). The *machambas* are small agricultural plots in urban and peri-urban areas in Mozambique where small entrepreneurs, in general women, cultivate vegetables to sell in the cities; they are an important source of food and income for many households in cities such as Maputo (Sheldon, 1999).

In the historical evolution of agroecology as a science (**Figure 2b**), the scale and dimension of research in agroecology have been enlarged from (i) the plot, field or animal scale to (ii) the farm or agroecosystem scale and, finally, to (iii) the whole food system, which is increasingly becoming a focus for agroecology (Wezel and Soldat, 2009).

Figure 2 Historical evolution of Agroecology



Sources: (A) adapted from Silici (2014), based on Wezel *et al.* (2009) and Wezel and Soldat (2009);
(B) adapted from Wezel *et al.* (2009).

Note: (C) illustrates the disciplinary basis of the principles of agroecology articulated in Section 1.2.

1.1.2 Agroecology as a set of practices

In the 1960s, in particular following the publication of Rachel Carson's book *Silent spring* (Carson, 1962), concerns emerged about unexpected impacts of the intensive use of synthetic inputs in agriculture on the environment, particularly about the concentration of pesticide residues through food chains impacting birds of prey.

Partly in response to this, a set of agroecological practices emerged over the next few decades (see Section 1.5, **Figure 3**) aiming at moving away from what has been called an "industrial agriculture model" towards more environmentally friendly and sustainable agricultural systems, optimizing the use of biological processes and ecosystem functions (Hernández Xolocotzi, 1977; Rosset and Altieri, 1997; Wezel *et al.,* 2009; Vanloqueren and Baret, 2009; Altieri *et al.,* 2012a; Wibbelmann *et al.,* 2013; Pimbert, 2015; IPES-Food, 2016; FAO, 2016b; Wezel *et al.,* 2014; Deguine *et al.,* eds, 2017; Wezel, 2017). Agroecology, as a set of practices, aims at designing complex and resilient agroecosystems that, by *"assembling crops, animals, trees, soils and other factors in spatially and temporally diversified schemes, favour natural processes and biological interactions that optimize synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity"* (Altieri, 2002).

Attempts to define which specific practices can be qualified as agroecological are only recently emerging. For example, Wezel *et al.* (2014) describe agroecological practices as *"agricultural practices aiming to produce significant amounts of food while valuing ecological processes and ecosystem services by integrating them as fundamental elements"*. For Shiming and Gliessman (2016), *"agroecological practices are those ecologically sound methods which can balance and enhance all ecosystem services provided by agroecosystems and hence benefit to the sustainable development of agriculture"*.

However, there is no definitive set of practices that can be labelled as agroecological, nor clear, consensual boundaries between what is agroecological and what is not (Wezel, 2017). On the contrary, agricultural practices can be classified along a spectrum and qualified as more or less "agroecological", depending on the extent to which: (i) they rely on ecological processes as opposed to the use of agrochemical inputs; (ii) they are equitable, environmentally friendly, locally adapted and controlled; and (iii) they adopt a systemic approach, rather than focusing only on specific technical measures.

Agroecological practices involve processes such as: nutrient cycling; biological nitrogen fixation; improvement of soil structure and health; water conservation; biodiversity conservation and habitat management techniques for crop-associated biodiversity; carbon sequestration; biological pest control and natural regulation of diseases; diversification, mixed cultivation, intercropping, cultivar mixtures; and waste management, reuse and recycling as inputs to the production process, for example use of manure and compost (Reijntjes *et al.,* 1992; Altieri 1995; Nicholls *et al.,* 2016; Wezel *et al.,* 2014; Wezel, 2017). Agroecological practices include, for instance, agroecological responses to new pest epidemics such as the recent spread of fall armyworm in Africa (**Box 5**) or crop–animal integration in traditional systems such as the rice–duck–fish system in Asia (**Box 6**).

Some of these practices have been applied to varying extents in different parts of the world for decades, while others have emerged more recently with as yet limited levels of adoption (Wezel *et al.,* 2014; Wezel and Silva, 2017). For example, organic fertilization, split fertilization, reduced tillage, drip irrigation, biological pest control, integrated pest management and choice of cultivars resistant/tolerant to biotic stresses (diseases, insect pests and parasitic weeds) are already widely integrated into temperate agriculture, in small- and larger-scale farms. Biofertilizers, natural pesticides and biopesticides, diversified rotations, intercropping and relay intercropping, agroforestry, allelopathic plants, direct seeding into living cover crops or mulch, and integration of semi-natural landscape elements at field, farm and landscape scales are less present in temperate agriculture, but prevalent in some tropical contexts (Leakey, 2014). Some agroecological practices, such as organic fertilization and intercropping, came into use with the development of organic agriculture in the 1940s.

Box 5 Agroecological practices to control fall armyworm in Africa

Fall armyworm (FAW), a voracious agricultural pest native to North and South America, was first detected on the African continent in 2016 (Goergen *et al.*, 2016). Since then it has spread across sub-Saharan Africa affecting thousands of hectares of cropland, causing up to USD13 billion per annum in crop losses (Abrahams *et al.*, 2017) and threatening the livelihoods of millions of farmers. In their haste to respond to FAW, governments have sometimes relied heavily on agrochemicals that, beyond the risks they can pose on human health and the environment, are likely to undermine biological pest management strategies (Abate *et al.*, 2000; van Huis and Meerman, 1997; Wyckhuys and O'Neil, 2010).

Agroecological approaches can offer locally adapted, low-cost, biological pest control options, including:

- sustainable soil and land management (e.g mulching), which improves crop health and resilience to pest attack (Altieri and Nicholls, 2003; Clark *et al.*, 1993; Rivers *et al.*, 2016);
- intercropping, which can reduce egg-laying by pests through deterrence by volatile chemicals released by intercrop plants (Midega *et al.*, 2018), trapping emerging FAW larvae, increasing their mortality (van Huis, 1981) and providing habitat for natural enemies within the field (Rivers *et al.*, 2016);
- crop rotation, which improves soil fertility and diversifies the farm environment (Wyckhuys and O'Neil, 2007; Meagher *et al.*, 2016; Rivers *et al.*, 2016);
- weeds, shrubs, trees and (semi-) natural habitats managed at multiple spatial scales, in fields or at field margins, which can provide habitat for a variety of natural pest enemies (Bàrberi *et al.,* 2010; Maas *et al.*, 2013, 2016; Meagher *et al.*, 2016; Wyckhuys and O'Neil, 2007; Bàrberi *et al.*, 2010; Sisay *et al.*, 2018; Leakey, 2014; Morris *et al.*, 2015; van Huis, 1981; Offenberg, 2015);
- regular scouting by the farmer to identify pests and assess damage that informs pest management decisions (McGrath *et al.*, 2018);

Agroecological practices are now being advocated as a core component of integrated pest management programmes for FAW in sub-Saharan Africa in combination with crop breeding, classical biological control and selective use of chemical pesticides (Harrison *et al.*, 2019; Thierfelder *et al.*, 2018).

Box 6 Traditional rice–fish–duck system in Hani terraces, Southwest China

The rice–fish–duck system is an important traditional agroecosystem in Hani terraces in Yunnan Province, Southwest China. Integration of crops and animals and circular economy are at the heart of this system. Fish and ducks eat weeds and pests and loosen the soil to improve the growing environment for rice, while rice provides food, shade and shelter for fish and ducks.

Pesticides and herbicides cannot be used in this system because of their toxicity to fish and ducks. Therefore, products from rice–fish–duck systems are very popular in consumer markets. Their prices are usually several times higher than the prices of conventional products. For example, the prices of red rice, fish and ducks raised in paddies in Hani terraces are respectively 5, 3 and 2.5 times higher than conventional prices.

An improved rice–fish–duck system has been experimented with in Hani terraces and is now popularized. The agroecosystem efficiently exploits the three-dimensional space (and seasonality) of paddies for developing rice–fish co-culture during the crop growing season while ducks are reared in winter during the fallow period. Its economic value is estimated to be 7.8 times that of the current conventional model that only grows the hybrid rice monoculture in summer for half the year and fallows the field in winter (Zhang *et al.,* 2017).

This is an example of a Globally Important Agricultural Heritage System (GIAHS) that combines agricultural biodiversity, resilient ecosystems, local communities and a valuable cultural heritage.[15] There is a network of 50 GIAHS sites in 20 countries of the world (FAO, 2002; Koohafkan and Altieri, 2010; Koohafkan and Cruz, 2011; HLPE, 2017b).

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[15] See: http://www.fao.org/giahs/en/

1.1.3 Agroecology as a social movement

Traditional agricultural systems, in their diversity, are the result of the co-evolution of ecosystems and human communities across many generations. Therefore, agroecosystems cannot be separated from the human communities living in them: social and political dynamics are at the heart of agroecology (Altieri, 2004b; Wibbelmann *et al.,* 2013; Ploeg and Ventura, 2014).

Agroecological approaches often arise in response to agrarian crises, and along with broader efforts of social movements to initiate widespread changes (Mier y Terán *et al.*, 2018 ; **Box 7**). These social movements advocate for a strong connection to be made between agroecology, the right to adequate food and food sovereignty.

The concept of food sovereignty was first introduced in international discussions during the World Food Summit in 1996, Rome, by La Via Campesina, an international movement of peasants. In 2007, civil society organizations (CSOs) and social movements gathered in Nyéléni, Mali, defined ***food sovereignty*** as *"the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems"* (Nyéléni, 2007). The initial set of seven principles of food sovereignty included: (i) food as a basic human right; (ii) the need for agrarian reform; (iii) protection of natural resources; (iv) reorganization of food trade to support local food production; (v) reduction of multinational concentration of power; (vi) fostering of peace; and (vii) increasing democratic control of the food system (La Via Campesina, 1996).

In February 2015, eight years after this first International Forum for Food Sovereignty, diverse social movements and organizations representing small-scale food producers gathered again in Nyéléni for an International Forum on Agroecology (Nyéléni, 2015). In their final declaration, they consider *"agroecology as a key element in the construction of food sovereignty".* For them, agroecology is not only *"a narrow set of technologies"* but, above all, a political struggle, requiring people to *"challenge and transform structures of power in society"*, addressing power imbalances and conflicts of interest, in order to *"generate local knowledge, promote social justice, nurture identity and culture, and strengthen the economic viability of rural areas"*.

Agroecology has thus become the political framework under which many social movements and peasant organizations around the world defend their collective rights and advocate for a diversity of locally adapted agriculture and food systems practised by small-scale food producers in different territories (Anderson *et al.,* 2015; Nyéléni, 2015). Agroecology is seen as a bottom-up pathway to food sovereignty, building on traditional knowledge systems, supported rather than led by science, where small producers, their communities and organizations, rather than agrifood business, play a central role. Agroecological approaches aim at building resilient and sustainable local food systems, strongly linked and adapted to their territories and ecosystems (Varghese and Hansen-Kuhn, 2013; Nyéléni, 2015; Anderson *et al.,* 2015). Some national governments have adopted policies embracing the principles of agroecology and food sovereignty in order to transform food systems (Altieri *et al.,* 2012b; Wezel *et al.,* 2009; Lambek *et al.,* 2014).

Box 7 *Rede Ecovida* in Southern Brazil

The *Rede Ecovida* or "Ecolife Network" is a decentralized system of cooperatives, farmer groups and non-profit organizations that practise agroecology in 150 municipalities in three southern Brazilian states. The network developed in the 1970s as part of broader social movements mobilizing around issues of environmental damage from agriculture, of high social inequalities and uneven land distribution.

Ecovida currently comprises 29 farmers' organizations, 2 700 farming households, 10 cooperatives, 25 associations, 180 farmers' markets and 30 agrifood private companies. Beyond profit, this network promotes a solidarity economy between producers and consumers in local markets (including door-to-door sales, community canteens, farmers' markets and restaurants). It uses participatory certification to ensure that farming practices are rooted in agroecology and strengthen the relationships/links/trust among farmers and with urban consumers. Overall, this network promotes horizontal learning methods, solidarity, justice and care for nature.

Sources: Perez-Cassarino (2012); Mier y Terán *et al.* (2018).

1.1.4 Agroecology as an innovative approach to sustainable food systems for food security and nutrition

As discussed above, there are an increasing number of definitions for agroecology provided in recent years that have different nuances depending on the authors, institutions or CSOs that provide them. What they have in common is the goal to develop SFSs. Regarding these different definitions and the specific focus of this report on FSN, rather than presenting yet another definition of agroecology *per se*, a definition of an agroecological approach to SFSs for FSN is offered based on the analysis and information presented in this chapter (**Definition 2**).

Definition 2 Agroecological approach to sustainable food systems for food security and nutrition

Agroecological approaches favour the use of natural processes, limit the use of purchased inputs, promote closed cycles with minimal negative externalities and stress the importance of local knowledge and participatory processes that develop knowledge and practice through experience, as well as more conventional scientific methods, and address social inequalities. Agroecological approaches recognize that agrifood systems are coupled social–ecological systems from food production to consumption and involve science, practice and a social movement, as well as their holistic integration, to address FSN.

1.2 Principles of agroecology

Scientists have developed different sets of agroecological principles (Reijntjes *et al.,* 1992; Altieri, 1995; Altieri and Nicolls, 2005; Stassart *et al.,* 2012; Dumont *et al.,* 2013, 2016; Nicholls *et al.,* 2016; Peeters and Wezel, 2017; all summarized in Migliorini and Wezel, 2018). Civil society networks also conducted the same exercise (e.g. Nyéléni, 2015; CIDSE, 2018). Today, agroecology is associated with a set of principles for agricultural and ecological management of agrifood systems as well as some wider ranging socio-economic, cultural and political principles (e.g. CIDSE, 2018). These latter principles have emerged only recently in the literature, arising from the activity of agroecological social movements (**Figure 2c**).

FAO (2018c) identified ten elements of agroecology to guide the transition towards sustainable agriculture and food systems.[16] These consolidated FAO ten elements are based upon seminal scientific literature on agroecology (in particular: Altieri, 1995; Gliessman, 2007) and upon the extensive and inclusive multi-stakeholder dialogues, gathering states and intergovernmental organizations, CSOs and private actors, held at global, regional and national levels since the first FAO International Symposium on Agroecology (September 2014).

Building on all these efforts, the HLPE elaborated a consolidated list of 13 principles, combining and reformulating principles from the three principal sources (Nicholls *et al.,* 2016; CIDSE, 2018; FAO, 2018d) to produce a minimum, non-repetitive but comprehensive set of agroecological principles. These are organized around the three operational principles for SFSs set out in the introduction – improve resource efficiency, strengthen resilience and secure social equity/responsibility (see **Table 1**). Each agroecological principle was allocated to the operational principle to which it most clearly contributes. However, given the interlinkages among these three categories, this classification is not fully discrete. For example, principles 3, 5 and 6 contribute not only to resilience but also to resource efficiency. Principles are also related to the FAO ten elements.[17]

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[16] Diversity; co-creation and sharing of knowledge; synergies; efficiency; recycling; resilience; human and social values; culture and food traditions; responsible governance; circular and solidarity economy.

[17] See: http://www.fao.org/3/i9037en/I9037EN.pdf

Different principles can be implemented at or impact different scales, from local to global, from the field to the whole food system. At the agroecosystem or landscape scale, some ecological processes, such as water flows, operate over large distances so that what farmers do in one location may impact other people positively (clean water supply) or negatively (flooding or contaminated water) many kilometres away, across administrative and national boundaries (Jackson *et al.*, 2013). Soil eroded from one place may be deposited and support food production elsewhere. Recent research has shown that not only surface water flow but also atmospheric transfers across continents are important, so that change in vegetation cover in the East African highlands impacts rainfall and hence agricultural productivity in the Sahel (van Noordwijk *et al.*, 2014).

This means that concepts of resource cycles and flows (principles 1 and 5) need to be related to the scales at which they operate, and many ecosystem services, such as pollination, quantity and quality of water provision and habitat provision for biodiversity conservation, only manifest at landscape scale and, hence, can only be managed by collective action of farmers and other stakeholders (Pagella and Sinclair, 2014). Application of agroecological principles often aims at reducing externalities associated with current models of agricultural production. Measuring and valuing ecosystem service provision at a range of scales is a key area of innovation required to measure performance of food systems in ways that address their sustainability. This is further developed in Chapters 2 and 3.

All these agroecological principles contribute, in different direct and indirect ways, to FSN. For instance, principle 2 (reducing the dependency on purchased inputs) can reduce food insecurity in particular for smallholders and for poor farmers because less money is spent on buying inputs and so there is less reliance on credit and, therefore, potentially more resources to buy food (Snapp *et al.,* 2010; Kangmennaang *et al.,* 2017; Hwang *et al.,* 2016). This is a primary motivation for the Zero Budget Natural Farming (ZBNF) agroecological movement in India (**Box 8**). Principle 9 (social values and diets) together with 5 (biodiversity) impact nutrition directly (Jones *et al.,* 2014b; Powell *et al.,* 2015; Bellon *et al.,* 2016; Demeke *et al.,* 2017; Lachat *et al.,* 2018; HLPE, 2017a,b). Co-creation of knowledge (principle 8) can also have indirect positive impacts on FSN (**Box 9**). Principle 11 (connectivity) may contribute to strengthen local economies, increasing the proportion of value added remaining on farms and enabling producers to better meet the food needs and demands of local consumers. This latter point can be supported by strong social organizations, which foster greater participation of local food producers and consumers in decision-making (principle 13).

Table 1 Consolidated set of 13 agroecological principles

Principle	FAO's ten elements	Scale application*
Improve resource efficiency		
1. Recycling. Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.	Recycling	FI, FA
2. Input reduction. Reduce or eliminate dependency on purchased inputs and increase self-sufficiency	Efficiency	FA, FO
Strengthen resilience		
3. Soil health. Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and enhancing soil biological activity.		FI
4. Animal health. Ensure animal health and welfare.		FI, FA
5. Biodiversity. Maintain and enhance diversity of species, functional diversity and genetic resources and thereby maintain overall agroecosystem biodiversity in time and space at field, farm and landscape scales.	Part of diversity	FI, FA
6. Synergy. Enhance positive ecological interaction, synergy, integration and complementarity among the elements of agroecosystems (animals, crops, trees, soil and water).	Synergy	FI, FA
7. Economic diversification. Diversify on-farm incomes by ensuring that small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.	Part of diversity	FA, FO
Secure social equity/responsibility		
8.Co-creation of knowledge. Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.	Co-creation and sharing of knowledge	FA, FO
9. Social values and diets. Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.	Parts of human and social values and culture and food traditions	FA, FO
10. Fairness. Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights**.**		FA, FO
11. Connectivity. Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies**.**	Circular and solidarity economy	FA
12. Land and natural resource governance. Strengthen institutional arrangements to improve, including the recognition and support of family farmers, smallholders and peasant food producers as sustainable managers of natural and genetic resources.	Responsible governance	FA, FO
13. Participation. Encourage social organization and greater participation in decision-making by food producers and consumers to support decentralized governance and local adaptive management of agricultural and food systems.		FO

*Scale application: FI = field; FA = farm, agroecosystem; FO = food system
Source: derived from from Nicholls *et al.*, 2016; CIDSE, 2018; FAO, 2018c.

It has been suggested that for agroecology to significantly impact FSN and generate sustainable diets,[18] power inequalities must be addressed within the food system at multiple scales and in different dimensions (HLPE, 2017a; Mier y Teran *et al.,* 2018; Pimbert and Lemke, 2018). Horizontal teaching methods (principle 8) are options for agroecology to address social inequalities; principles 10–13 articulate how other inequalities can be addressed as part of an agroecological approach.

Potential trade-offs must also be considered in each specific context. For instance, depending on quantity and type of inputs, reduced input use (principle 2) could lead to lower productivity, lower income and thus higher food insecurity. In addition, agroecological methods, if more labour-intensive, could increase women's workload, leading to worsening the nutritional status of children if gender relationships within households are not changed (principle 9).

Box 8 Zero Budget Natural Farming – Scaling-up agroecology in India

Zero Budget Natural Farming (ZBNF) is both a set of farming methods and a grassroots peasant movement in India born in Karnataka. It is estimated that ZNBF methods are used by 100 000 farming families in Karnataka, and by millions of families at the national level. In 2015 the Government of Andhra Pradesh announced its objective to reach 500 000 farmers with ZBNF by 2020.

Interest in ZBNF methods arose partly because of the high rates of farmers' debt, originating from the costs of fertilizers, seeds, energy and equipment (mechanization and irrigation), which have been linked to high suicide rates. More than a quarter of a million farmers have committed suicide in India in the last two decades.

"Zero Budget", which means not relying on credit, and not buying inputs, promises to put an end to heavy debt, by drastically reducing production costs. "Natural Farming" means farming *with* nature and *without* purchased chemical inputs. ZBNF methods include: mulching; intercropping; controlled irrigation; contour bunds; use of local earthworm species and fermented microbial culture; combined seed treatment with cow dung, sugar, pulse flour, urine and soil.

At the local level, ZBNF operates mainly through volunteers, members of farmer organizations and community leaders, motivated by the founder of the movement, Subhash Palekar, an agricultural scientist who has written many publications on ZNBF methods. At the state level, intensive five-day training camps are held, with support from volunteers and allied organizations. A survey of 97 ZBNF farmers reported increased yield, seed diversity, product quality, household food autonomy, income and health, along with reduced farm expenses and credit needs.

The following strategic elements were critical for the successful implementation of ZBNF in India:

- **Charismatic leadership.** A highly charismatic teacher, Subhash Palekar has played a key role in motivating and promoting ZBNF methods through books, training courses and other public appearances.
- **Horizontal pedagogical practices.** While Palekar teaches in a more vertical manner, most of the teaching is done through farmer-to-farmer exchanges and mentoring.
- **Supportive public policy.** Training is provided at the state level in several Indian states.
- **Local and favourable markets.** At least eight shops exclusively retail ZBNF products in cities such as Bangalore and Mysore, but marketing remains a challenge.
- **Strong social organization.** States organize training camps and informal networks support training and ongoing support for ZBNF with links to allied organizations.
- **Efficient farming practices.** Farmers report improved yields, food quality and income, and reduced farm expenses and credit.
- **Cultural relevance.** ZBNF methods address the credit and debt concerns of farmers in socially and culturally adapted ways.

Sources: Khadse *et al.* (2018) ; Kumar (2018); La Via Campesina (Undated)

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[18] "Sustainable diets are those with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (FAO, 2012a).

Box 9 Participatory agroecology research to address food security and nutrition in Malawi

Using participatory education and agroecology in Malawi, thousands of rural families have seen dramatic improvements in maternal and child nutrition, food security, crop diversity, land management practices and gender equality. Central to the success of this long-term programme has been iterative, participatory, transdisciplinary research methods that used multiple measures to assess and improve farming and social change with participating farmers (Bezner Kerr and Chirwa, 2004; Nyantakyi-Frimpong *et al.,* 2017). Agroecology education was integrated with nutrition and social equity issues through interactive, dialogue-based methods, such as recipe days, discussion groups and theatre (Satzinger *et al.* 2009; Bezner Kerr *et al.,* 2016a; Bezner Kerr *et al.,* 2018a). Peer-driven farmer-led methods mobilized communities to test and use agroecological practices such as legume intercrops, compost, agroforestry and crop diversification (Bezner Kerr *et al.,* 2007; Bezner Kerr *et al.* 2018b; Owoputi *et al.,* 2018). When farmers used more agroecological practices, such as the incorporation of nutrient-rich legumes into maize-based cropping systems, yields stabilized, fertilizer costs fell and soil cover increased (Snapp *et al.,* 2010; Kangmennaang *et al.,* 2017; Owoputi *et al.,* 2018). Households using agroecological practices who participated in community education programmes had significant improvements in child growth, food security, maternal dietary diversity and self-reported health (Bezner Kerr *et al.,* 2010; Nyantakyi-Frimpong *et al.,* 2016a; Owoputi *et al,.* 2018). There was also evidence of improved gender and other forms of social equity in communities for households with HIV-positive family members (Bezner Kerr *et al.,* 2016b, 2019; Nyantakyi-Frimpong *et al.,* 2016b). In households where spouses began discussing farming practices with each other, there were higher levels of food security and dietary diversity. Farmers began to take more pride in their own experimentation, traditional knowledge and ability to mentor others (Bezner Kerr *et al.,* 2018b). Some communities organized the sharing of seeds and agroecological knowledge, and reported greater resilience under conditions of poor rainfall due to improved soil quality (Bezner Kerr *et al.,* 2018b, 2019).

Key findings from the case study:

- Farmer-to-farmer teaching and experimentation were the primary teaching approaches and were effective at sharing knowledge.
- Unequal social relationships including gender inequalities were assessed, discussed and improved over time.
- Relevant educational strategies were developed by local communities to address these inequalities in an iterative way.
- Linking agroecology to FSN outcomes took at least two years before such outcomes were realized, and required transdisciplinary and participatory approaches.

1.3 Contribution of agroecological approaches to food security and nutrition for rural consumers in low-income countries

Not only do agroecological practices contribute to FSN, but they also contribute to 10 of the 17 SDGs (UN, 2015) through integrated practices that cut across many areas (FAO, 2018a) and help address poverty and hunger, education, gender equality, decent work and economic growth, reduced inequalities, responsible consumption and production, climate action, life on land, and peace and justice. Along with the SDGs, agroecology can also contribute to the Koronivia Joint Work on Agriculture (KJWA) (St-Louis *et al.,* 2018) on adaptation, soils, nutrient use, manure management and livestock systems (see points 2.c, 2.d, and 2.e of the KJWA), and help realize the aims of the Paris Climate Agreement, the CBD and the United Nations Convention to Combat Desertification (FAO, 2018a).

Beyond yield and production, an assessment of the contribution of agroecological approaches to FSN needs to incorporate multiple metrics that take into account social, economic and environmental impacts of agriculture.

Agroecological approaches could play an important role in securing sustainable diets for all now and in the future as part of a transition towards more sustainable food systems that enhance FSN (De Schutter, 2011, 2012; IPES-Food 2016, DeLonge *et al.,* 2016). Numerous studies have found positive relationships between diversified farming systems (a key principle of agroecology), household dietary diversity and nutrition (Talukder *et al.,* 2000; De Clerck, 2013; Oyarzun *et al.,* 2013; Jones *et al.,* 2014b; Khoury *et al.*, 2014; Carletto *et al.,* 2015; Kumar *et al.,* 2015; Olney *et al.,* 2015; Shively and Sununtnasik, 2015; Jones, 2017).

Bliss *et al.* (2017) examined the diversified farming systems of 30 Nicaraguan households. For the farmers, dietary diversity was a driver for diversification on fields, and the related higher crop diversity, with difference in harvest time, meaning greater food availability throughout the year. In Southern Benin, Bellon *et al.* (2016) found a positive correlation between on-farm diversity and women's dietary diversity score (DDS),[19] as most of the food grown on-farm was for consumption rather than for sale. Jones *et al.* (2018) also found that on-farm agrobiodiversity was associated with more diverse and micronutrient-adequate diets among women in the Peruvian Andes.

In a survey of 390 households in Mexico, Becerril (2013) found improved body mass indexes in households using the diversified traditional "milpa" system (intercropping of maize, beans and squash) compared to other households with less diversified farming systems. In their study on Guatemala's Mayan Achí people, Luna-González and Sørensen (2018) found that nutritional functional diversity and DDSs were positively correlated with higher crop and animal species diversity (derived from traditional intercropped milpa systems, home gardens, local market, wild gathering) but higher DDDs were not correlated with better child anthropometric status. Other factors, such as limited access to health care or safe water, may have prevented improved child growth. In northern Malawi, studies have shown that legume intercropping, along with a participatory approach sensitive to cultural values and promoting gender equality, enhanced both food and nutritional security (Bezner Kerr *et al.*, 2016c; Nyantakyi-Frimpong *et al.*, 2016b; see **Box 9**). These results are especially significant as many Malawian households experience food insecurity and malnutrition (Ecker and Qaim, 2011) leading to poor health outcomes including stunting in young children (FAO, 2014a).

In Uzbekistan, Gotor *et al.* (2018), studying a programme related to conservation and use of fruit species, showed that families growing more fruit species consumed a greater proportion of fruits in their diets, increasing their dietary diversity. Dawson *et al.* (2013) showed that agroforestry practices exploit differences in the phenology of fruit-tree species to provide critical nutritional supplements (particularly Vitamins A, C and B6) and maintain dietary diversity throughout the year. They highlighted that their extensive root systems allow trees to store water, be productive and contribute to dietary diversity, even in dry environments, in seasons when herbaceous vegetation cannot survive without irrigation. In Machakos (Kenya), an average household can achieve year-round dietary diversity with 20 trees of ten species either dispersed throughout their farm (on borders, around the home and in fields) or in a 8×18 m^2 (0.015 ha) fruit orchard (Kehlenbeck and McMullin, 2015). In a survey of 368 coffee-producing households, Bacon *et al.* (2017) found that food security was enhanced for agroforestry farmers who grew more of their own food and incorporated more diversified production elements including fruit trees and red bean crops. However, the authors cautioned that not all diversification is equally beneficial to different parameters of FSN. A meta-analysis revealed a significant positive relationship between indicators of dietary quality of children under five and landscape-scale tree cover in Africa, associated with maximum fruit and vegetable consumption at an intermediate level of tree cover (45 percent), after which it declines (Ickowitz *et al.*, 2014).

Diversified production in home gardens with application of agroecological practices provides an avenue for FSN for poor households with limited access to food. Home gardeners in Ghana, using intercropping, seed-saving, organic manures and crop residues as well as domestic waste, contributed to greater food availability, food access and nutrient supply (Bagson and Naamwintome, 2012). Vijayalakshmi and Thooyavathy (2012) found similar results in a study looking at the impact of home gardens on women's nutrition. In a small-scale study of 12 households in Bangladesh, Ferdous *et al.* (2016) highlighted a drastic increase in vegetable consumption among households trained in the Rangpur model (a home-garden strategy based on seven production niches, 14 vegetables selected for year-round cultivation, fruit and locally adapted crops). After the intervention, vegetable intake almost doubled, with 55–79 kg/person/year produced compared to 21–30 kg/person/year before the intervention.

Several studies revealed a positive impact of organic farming practices on FSN (Miyashita and Kayunze, 2016; da Silva *et al.*, 2018; Kamau *et al.*, 2018). Miyashita and Kayunze (2015), for example, found significant differences in terms of FSN when they compared organic and conventional farming in the United Republic of Tanzania. On the other hand, the study of 139 farming households by Kaufman (2015) in northern Thailand showed variable impact of organic agricultural systems on food security when compared to conventional counterparts. While organic farmers had slightly higher mean levels of food security and lower debt levels compared to conventional farmers, the findings

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[19] For more information about DDS see http://www.fao.org/3/a-i1983e.pdf

were not statistically significant (Kaufman, 2015). The author concludes that greater support for viable markets for organic products is needed to translate into significant differences in FSN for organic producers (Kaufman, 2015).

In contrast, some studies also showed no significant relationship with the application of agroecological practices and measured parameters related to FSN. For instance, on-farm diversification in Nigeria had no impact on household DDS for the poorest surveyed households, although greater diversity was evident with middle- and high-income households (Ayenew *et al.*, 2018). In Kenya, Ng'endo *et al.* (2015). also found no significant correlation between agrobiodiversity and households' FSN.

1.4 Contested areas and knowledge gaps in agroecology

There is no common, consensual definition of what constitutes an agroecological approach shared by all the actors involved (practitioners, scientists, social activists). Complete agreement on all the aspects embedded in the plurality if approaches or on how it should contribute to transformation of food systems is also lacking. While this makes it hard to pin down exactly what is agroecology and what is not, it also provides a flexibility that allows agroecological approaches to develop in locally adapted ways. It is thus necessary to examine key contested areas and knowledge gaps, which is the aim of this section.

1.4.1 Political and social dimensions of food production

Some scientists, food-system actors and social movements have diverging views about whether social and political dimensions of food production should be considered as an integral and indivisible part of agroecology, critical for agroecology to be transformative (Méndez *et al.,* 2013; Rosset and Altieri, 2017; Sanderson Bellamy and Ioris, 2017; Giraldo and Rosset, 2018). De Molina (2013) argues that not recognizing the social and political implications of agroecology could lead to negative social, environmental and FSN consequences for marginalized groups who may be disadvantaged with a "business as usual" model of agricultural improvement. This argument is in line with research on how political, social and economic context determines how technology is employed in addressing FSN (Bezner Kerr, 2012; Gómez *et al.*, 2013; Stone and Glover, 2017).

Some authors have suggested distinguishing a *political or transformative agroecology,* considering political and social factors to address FSN at a broader scale, from a *technically-focused agroecology* at the field scale (Méndez *et al.* 2013; Sanderson Bellamy and Ioris, 2017).

Attention has in particular been drawn to the importance of addressing context-specific gender and social inequalities and related labour and economic dimensions through agroecological approaches (Batello *et al.*, 2019; Bezner Kerr *et al.*, 2019). Other authors have noted that agroecology, when embedded within a larger food systems policy intervention or food sovereignty initiative, can have a positive impact on FSN (Kanter *et al.*, 2015; Wittman and Blesh, 2017).

A just food system (Pimbert and Lemke, 2018) addresses wages and working conditions within it (principle 10) creating a direct link to FSN. Improved livelihoods for farm labourers, producers, market intermediaries, entrepreneurs and processors may enable them to achieve higher incomes and, therefore, purchase food. Increased proximity of producers and consumers and re-embedded local food systems (principle 11) may contribute to improving local economies. For example, producers can profit by receiving a higher share of revenue if less is taken by intermediaries or actors over a long supply chain for marketing and distribution of produce. Also, local food enterprises and retailers can increase their price margins and become better linked and known to local consumers. An important point here is also that producers can respond more effectively to the real food needs and demands of local consumers. This latter point is strongly supported by social organizations, which foster greater participation and decision-making of food producers and consumers (principle 13).

1.4.2 Difficulty in providing labels: illustration through the convergence with organic agriculture

As agreeing on a generic definition proves to be difficult, so it is to provide universal label and labelling mechanisms. Yet, some initiatives by stakeholder groups and companies are under way. One form of certification that is suggested is the participatory guarantee system (PGS), in which certification is done using a democratic process involving producers, scientists and consumers (see **Box 32** in **Appendix 1**).

This may also generate difficulties when addressing distinction with other innovative approaches. There is, for example, a growing debate about similarities, difference and convergence of organic agriculture and agroecology (Migliorini and Wezel, 2018). There is also related debate about whether synthetic pesticides and chemical fertilizers should be excluded from agroecological production, as under organic agriculture (with a few exceptions), or be acceptable to a certain degree or in defined situations.

1.4.3 Can agroecology feed the world?

Some people think that farmers cannot feed the world with agroecology, others contend that it is impossible to feed the world in the future without agroecology. These echo divergent views on whether organic farming could feed the global population (De Ponti *et al.*, 2012, Muller *et al.,* 2017).

It is commonly estimated that an increase in agricultural production will be required to feed a growing global population, expected to reach 9.7 billion by 2050, unless major changes are made in global food systems (HLPE, 2016; Berners-Lee *et al.,* 2018; Le Mouël *et al.*, eds, 2018), especially in Africa (van Ittersum *et al.*, 2016). Estimates vary depending on whether food losses and waste, urbanization and changing diets, non-food uses (animal feed, biofuels and others) are considered in the modelling (HLPE, 2013b, 2014; Kahane *et al.,* 2013; Keating *et al.,* 2014; Berners-Lee *et al.,* 2018; Le Mouël *et al.*, 2018; Keating and Carberry, 2010; Alexandratos and Bruinsma, 2012; Valin, 2014). FAO (2017b) estimated that global agricultural production would have to increase by almost 50 percent between 2012 and 2050.

However, the need for such an increase in agricultural production is contested, as the earlier assumptions are challenged: some estimates indicate that enough food is produced today to potentially feed 9 billion people (IPES-Food, 2016; HLPE, 2014, 2017b; Chappell, 2018) or even 9.75 billion (Berners-Lee *et al.,* 2018). The debate as to whether or not agroecology can feed the world may be based on a false premise since, despite high levels of production, food insecurity and malnutrition still persist today (Chappell, 2018; HLPE, 2016, 2017b), even in food-exporting countries such as Brazil and South Africa (FAO *et al.*, 2017). Today, almost one-third of food produced for human consumption is either lost or wasted, yet different forms of malnutrition coexist in most countries (HLPE, 2014, 2017b). Globally, around 820 million people are still hungry (FAO *et al.,* 2018), about 2 billion are overweight or obese (Ng *et al.,* 2014) and an estimated 2 billion people suffer from malnutrition caused by micronutrient deficiencies (iron, iodine, vitamin A, folate and zinc) (HLPE, 2017b). FAO (2018e) found that a “business as usual” scenario is likely to lead to significant undernourishment by 2050 even if gross agricultural output increases by 50 percent. On the contrary, alternative “towards sustainability” scenarios, through more balanced diets, more sustainable production and consumption patterns, as well as through fairer food and income distribution, in line with agroecological approaches, could lead to a drastic reduction in undernourishment and improvement of nutritional security even if agricultural production increases only by around 40 percent.

Increasing production alone might thus not be sufficient to achieve FSN in its four dimensions (availability, access, utilization and stability) (FAO, 2018b). There is a growing awareness that hunger and malnutrition may not be only a matter of food production, but mainly of different entitlements, leading to unequal access to food, to natural resources (land, water, genetic resources), inputs, markets and services (Sen, 1981; Smith and Haddad, 2015; HLPE, 2017b). Previous HLPE reports have extensively discussed the issues raised by inequalities in access to food and resources (see in particular: HLPE, 2011a,b, 2012, 2013a, 2015, 2016, 2017c). Therefore, agroecological approaches are presented as promising avenues to achieve FSN, since they do not consider productivity alone and suggest addressing social inequalities and power asymmetries (Massett *et al.*, 2011 ; Kanter *et al.*, 2015; HLPE, 2018), including gender and ethnic minority inequalities (Massicotte, 2014; Bezner Kerr *et al.*, 2019).

Furthermore, ”feeding the world” is sometimes framed as a question of calories or production, and includes debates about the nutritional implications of different farming systems (HLPE, 2017b). Meeting kilocalorie energy requirements, however, does not translate automatically into nutritional security (Pingali, 2015; Traore *et al.,* 2012; Keating *et al.,* 2014), as some forms of calorie consumption (e.g. foods with high sugar, salt or fat content) can worsen nutritional status (HLPE, 2017b). FSN indicators now go beyond calorie count, and include measures of child growth, diet quality and reported experience of food insecurity at the individual and household level (Arimond *et al.,* 2010; Carletto *et al.,* 2012).

In many parts of the world, the so-called "industrial" agriculture model relying on the intensive use of fossil fuel and chemical inputs has resulted in increased agricultural productivity at the expense of loss of biodiversity, land degradation, loss of soil fertility and chemical contamination of soil and water, with major consequences on human, animal and planetary health (Kremen and Miles, 2012). A number of recent studies suggest that industrial agriculture cannot ensure sustainable food systems for FSN in the long term because of these negative impacts (Campbell *et al.*, 2017; Frison *et al.*, 2011; IPES-Food, 2016; Mahon *et al.,* 2017; Kremen and Merenlender, 2018). The consequences of such production systems in terms of diet imbalance are increasingly a polemical issue, which calls for increased attention from consumers (HLPE, 2017b).

Moreover, several studies challenged the common idea that agroecological systems are less productive than more "conventional" or "industrial" agricultural models (intensive and specialized), and thus cannot make a large contribution to feeding the world.

For example, Poux and Aubert (2018) have recently modelled the potential for agroecological approaches (including elimination of pesticides and synthetic fertilizers, shifting to healthier diets, and development of hedges, trees, ponds and other habitats for increased biodiversity) to feed Europe. They estimated that production would decline by 35 percent but that food requirements for Europe and for the export market in cereals, dairy and wine would be maintained, greenhouse gas emissions would be reduced by 45 percent and biodiversity and natural resources improved. Pretty *et al.* (2003), De Schutter (2010, 2012, Ponisio *et al.* (2015) and Reganold and Wachter (2016) summarized many examples, mainly from tropical and subtropical countries, showing significant yield increases associated with agroecological or organic farming. Pretty *et al.* (2003) showed that the weighted average increases were 37 percent per farm and 48 percent per hectare, while d'Annolfo *et al.* (2017) showed in their meta analysis that, following the adoption of agroecological practices, yields increased in 61 percent of the cases analysed and decreased in 20 percent, while farm profitability increased in 66 percent of cases.

Given the underinvestment in agroecological research noted below, it remains unclear how representative the cases so far documented are and which aspects of the agroecological approaches adopted were responsible for yield and profit improvements.

1.4.4 Knowledge systems

There are debates around the role and contribution of indigenous and local food producers in knowledge generation and the significance of cultural context for shaping this knowledge, including the role of women, elders, ceremonies, community organizations and opportunities for interaction with scientists (IAASTD, 2009; Etkin, 2006; Méndez *et al.,* 2013; Snapp and Pound, eds, 2017; IIED, 2018). Local knowledge is used here to refer to the knowledge held by a defined group of people (Sinclair and Walker, 1999). It embraces traditional knowledge (passed down from one generation to the next), indigenous knowledge that is culturally bound and locally derived knowledge from contemporary learning based on local observation and experimentation (Sinclair and Joshi, 2004). Some argue that traditional knowledge is deep, but narrow, while scientific knowledge is broad but shallow, and that agroecology involves the co-production of knowledge through the mutual shaping of different knowledge streams (Vandermeer and Perfecto, 2013). Scholars and indigenous groups also debate the notion that local knowledge is "new" scientific knowledge and caution about the dangers of such knowledge being separated out from other social–ecological knowledge (Barthel *et al.*, 2013; Massicotte, 2014; IIED, 2018). There is mounting evidence that much local agroecological knowledge is dynamic, based on contemporary observation and experimentation by farmers and comparable with and largely complementary to global scientific knowledge (Richards, 1985; Sinclair and Walker, 1999; Thorne *et al.*, 1999; IAASTD, 2009;Cerdán *et al.*, 2012; Kuria *et al.*, 2018). While some agroecological knowledge is widely held by people living in a particular locality (Joshi *et al.*, 2004), in other cases different people within communities may have different interests and opportunities to observe agroecological processes leading to marked differences in knowledge according to gender or other forms of social differentiation (Crossland *et al.*, 2018).

Debates about the roles of farmers and social movements in agroecological knowledge and agroecological research relate to the potential to "scale-out" agroecology effectively (Pimbert, ed, 2018a). Several scholars and social movements in the "political agroecology" stream have emphasized the significance of democratic processes in agroecological knowledge generation, with the process of small food producer-led, decentralized, autonomous knowledge generation being as important as the specific technical knowledge being generated through more formal scientific approaches (Massicotte, 2014). Researchers have also pointed to the need for agroecology to explicitly address gender, ethnic minorities and other social inequalities in order to effectively impact FSN (Massicotte, 2014; Bezner Kerr *et al.*, 2019).

These issues can create tensions between social movements and scientists. This may happen when the way science generates knowledge and judges its validity is not respected, when ethics and social control of scientific production are not addressed, when the contribution of non-academic actors in knowledge production is not considered. This is especially the case when investment decisions are being made and power imbalances exist. Consideration of these situations has led to explicit attempts to bridge across different knowledge systems (Mendez *et al.,* 2013; Tengö *et al.*, 2014).

1.4.5 Knowledge gaps

The severely limited public investment in agroecological approaches, estimated at between 1 percent and 1.5 percent of total agricultural and aid budgets, partly explains the remaining knowledge gaps (DeLonge *et al.*, 2016; Miles *et al.*, 2017; Pimbert and Moeller, 2018). Most private and public investments in agricultural research over the last 50 years were primarily based on "Green Revolution" technologies (including agrochemicals and mechanization) and, in particular, on genetics (Vanloqueren and Baret, 2009; DeLonge *et al.*, 2016; Miles *et al.*, 2017; Pimbert and Moeller 2018). For example, in the United Kingdom, aid for agroecological projects represents less than 5 percent of agricultural aid and less than 0.5 percent of its total aid budget since 2010 (Pimbert and Moeller, 2018). In the United States of America, research and development related to diversified systems – a major avenue for agroecological systems – amounts to less than 2 percent of public agricultural research funding (Carlisle and Miles, 2013). FAO estimates that 8 percent of their 2018–2019 work contributes to agroecological transitions (FAO, 2018f).

In addition, the majority of teaching and research institutions, and extension services, have been oriented to the so-called "industrial" agriculture rather than to the promotion of agroecological technologies. Typical education programmes in agronomy are mostly oriented towards single solution problem solving in conventional agriculture. There is now a growing number of education programmes that bring more systemic and holistic approaches, as well as experiential learning, into focus (Francis *et al.*, 2011, 2017).

Therefore, comparisons between agroecological approaches and the dominant "industrial" agriculture model need to consider the funding bias skewed against agroecological research, education and extension (Delonge *et al.,* 2016; Pimbert and Moeller, 2018).

Two key knowledge gaps are how to effectively link agroecology to public policies to address FSN (Sabourin *et al.*, 2018), and what are the economic and social impacts of agroecology for different groups in communities, including labour costs and FSN (Sanderson Bellamy and Ioris, 2017; Bezner Kerr *et al.*, 2019).

Assessing the yield gap between "industrial" and agroecological systems is an active area for research. Although several studies suggest that there are comparable yields, higher yield stability, particularly under extreme weather conditions, and increased profitability for those using agroecological methods, further research is required, in a wider range of socio-ecological conditions (d'Annolfo *et al.*, 2017; Sanderson Bellamy and Ioris, 2017).

How to scale out agroecological approaches in ways that foster democratic processes and address the needs of marginalized groups is also lacking, with some evidence for context-specific methods being effective at addressing FSN and SFSs, if political and economic barriers are addressed (IPES-Food, 2016; Mier y Terán *et al.,* 2018; Sinclair and Coe, 2019).

The design of resilient agricultural systems is an imperative to cope with climate change and increased climate variability. Resilience is particularly important in areas most likely to be affected by extreme climate events such as prolonged droughts, floods and heavy winds (Ching *et al.*, eds, 2011; Koohafkan *et al.*, 2012; Rhodes, 2013; Scialabba and Müller-Lindenlauf, 2010; Altieri *et al.*, 2015). Holt-Giménez (2002) indicated that agroecological systems are more adapted to such context, and might even help mitigate the effects of climate change. However, further research is needed to better understand the processes that support more resilient systems in different contexts. Many gaps remain in terms of how to support such transitions and what are the key barriers to overcome (Gliessman, 2016; Côte *et al.,* 2019). Several "lock-ins" that may prevent the transition towards agroecological systems have been identified, but would need to be better understood, including: path-dependency[20]; high labour costs; low energy costs; trade and agricultural policies that encourage the export orientation of agriculture, as well as the intensive use of fossil-fuel and chemical inputs; consumer expectations for cheap food and mass retail standards; compartmentalized, short-term thinking in research, politics and business; and inappropriate performance metrics (Vanloqueren and Baret, 2009; IPES-Food 2016; Roesch-McNally *et al.*, 2018). Concentration of power in food systems, in the input, processing and retail sectors, is a major lock-in that hampers transformative efforts towards SFSs for FSN (Howard, 2015; IPES-Food, 2016, 2017a, HLPE, 2017a) as dominant actors influence the framing of the research questions and the solutions provided in research, policy and business (IPES-Food, 2016). The persistence of "feeding the world" as an exclusive narrative is an example of this influence, since this only focuses on production imperatives at the expense of concerns about ecological health and the social impacts of food systems (Bené *et al.*, 2019).

1.5 Agroecological transitions to more sustainable food systems

Previous sections have described agroecology as providing possible transition pathways towards more sustainable farming and food systems, based on a holistic and systemic approach (IPES-Food, 2016; Elzen *et al.*, eds, 2017). Gliessman (2007, 2016) identified five different levels in agroecological transitions illustrated in **Figure 3**.

At the first level, this transition pathway focuses on improving *resource efficiency* through practices that reduce or eliminate the use of costly, non-renewable, scarce or environmentally damaging inputs. At the second level, alternatives to chemical inputs are envisaged with the view to relying more on ecological processes, taking advantage, for instance, of co-existing biota (such as the plant microbiome or natural enemies) or genetics characteristics (such as cultivars that are resistant/tolerant to biotic stresses) to improve plant nutrient uptake, stress tolerance and defences against pests and diseases (Singh *et al.*, 2018).

Whereas levels 1 and 2 are incremental, levels 3 to 5 are transformational. Level 3 aims at redesigning the farming system to strengthen its resilience*,* including through diversification, recycling, improved soil management, self-sufficiency and reduced dependency on purchased inputs (Côte *et al.,* 2019). An example is the enhancement of diversity in farm structure and management with diversified rotations, multiple cropping, agroforestry and the (re-)integration of animals and crops. At this level, there is a strong focus on managing interactions among components of the agroecosystem (animals, crops, trees, soil and water) – for example through the strategic use of crop residues as mulch or animal feed – and on increasing synergies at farm and landscape scales.

Transition levels 4 and 5 broaden the focus to encompass the whole food system. Level 4 aims at reconnecting producers and consumers through alternative food distribution networks such as farmers' markets, community-supported agriculture, or fair trade in food products, contributing to secure *social equity/responsibility*. Finally, level 5 involves building a new global food system that is not only sustainable but also helps restore and protect Earth's life-support systems. The ultimate goal is to design food systems that ensure FSN for all, now and in the future in a sustainable way. **Box 10** illustrates the transition towards SFS currently implemented in the Drôme Valley (France).

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[20] According to IPES-Food (2016), the high level of upfront investments required in "industrial" agriculture models makes it very hard for farmers to make structural changes in their production system.

Box 10 Territorial approach to sustainable food systems: *La Vallée de la Drôme-Diois* (France)

In southeast France, the territory called *Vallée de la Drôme-Diois*, with around 54 000 inhabitants in 2006 (INSEE, 2011), comprises diverse agroecosystems including livestock rearing in mountainous areas, wine, cereal, fruit and lavender production on hillsides, and cereals, poultry, walnut and fruit production in lower valley regions. Organic agriculture, using farmer-to-farmer knowledge sharing, combined with cooperatives and organic supply chains, has emerged as a significant source of livelihoods, with 40 percent of organic farmers in the Valley (compared to only 8 percent country-wide).

The Biovallée project aims to make the Drôme Valley and its adjacent area an ecological leader through a multi-pronged approach aiming at: (i) reducing energy consumption by 20 percent in 2025 and by 50 percent in 2040 and producing local renewable energy to cover 25 percent of local needs in 2025 and 100 percent in 2040; (ii) converting half of the farmers and of the area to organic agriculture by 2020; (iii) protecting rural land from urbanization; (iv) offering 80 percent of organic or local products in collective/institutional catering by 2025; (v) reducing by half the waste routed to treatment centres by 2025; (vi) creating 2 500 new jobs on the territory in sustainable sectors by 2025; (vii) investing in research, education and capacity building on sustainable development to create employment.

As part of this initiative, a social innovation in supply chain infrastructures and intersectoral collaboration was developed. A Committee for the Agricultural Development of the *Diois* provided a platform for organic agriculture experimentation, market, technical advice and training. A large-scale food hub and vegetable-processing factory was built, which facilitated the public procurement of organic foods, and their distribution in school canteens and day-care centres. A social enterprise, *La Carline*, governed by producers, consumers and employees, connected local consumers to organic producers, and grew from 30 to 600 families, with an annual turnover of EUR 1.2 million in 2014. There were independent organic input providers, cooperatives, trade unions and municipal councils that had already developed networks before the Biovallée project.[21]

Interactions between organic and conventional farmers were facilitated by newly formed agricultural knowledge exchange groups (Centre d'études technique agricoles – CÉTAs), as well as by the participation of organic farmers in local cooperatives, sometimes as administrative council leaders. These interactions led to the progressive development of organic agriculture from a small fringe niche to an institutionalized mainstream market offering a new agricultural model and inspiring farmers to adopt best sustainable practices. The Chamber of Agriculture developed organic extension services and currently the Valley has the highest number of organic extension advisers in France. Several sustainable agriculture and development training centres are now established in the Drôme Valley.

Local support for cooperatives and supply chains from municipalities increased as they became interested in promoting the larger Valley region as a territory of high-quality, ecological production and sustainable development. The 2012 French national strategy with the agroecology project for France has also supported initiatives in the Valley.[22]

Overall, the Drôme Valley, through a mixture of organic agriculture research and capacity building, public procurement and innovations in social enterprises, has experienced a significant increase in diversified organic production, consumption and related business opportunities.

Sources: Ministère français de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'aménagement du territoire (2010); INSEE (2011); Wezel and David (2012); Bui (2015); IPES-Food (2018).

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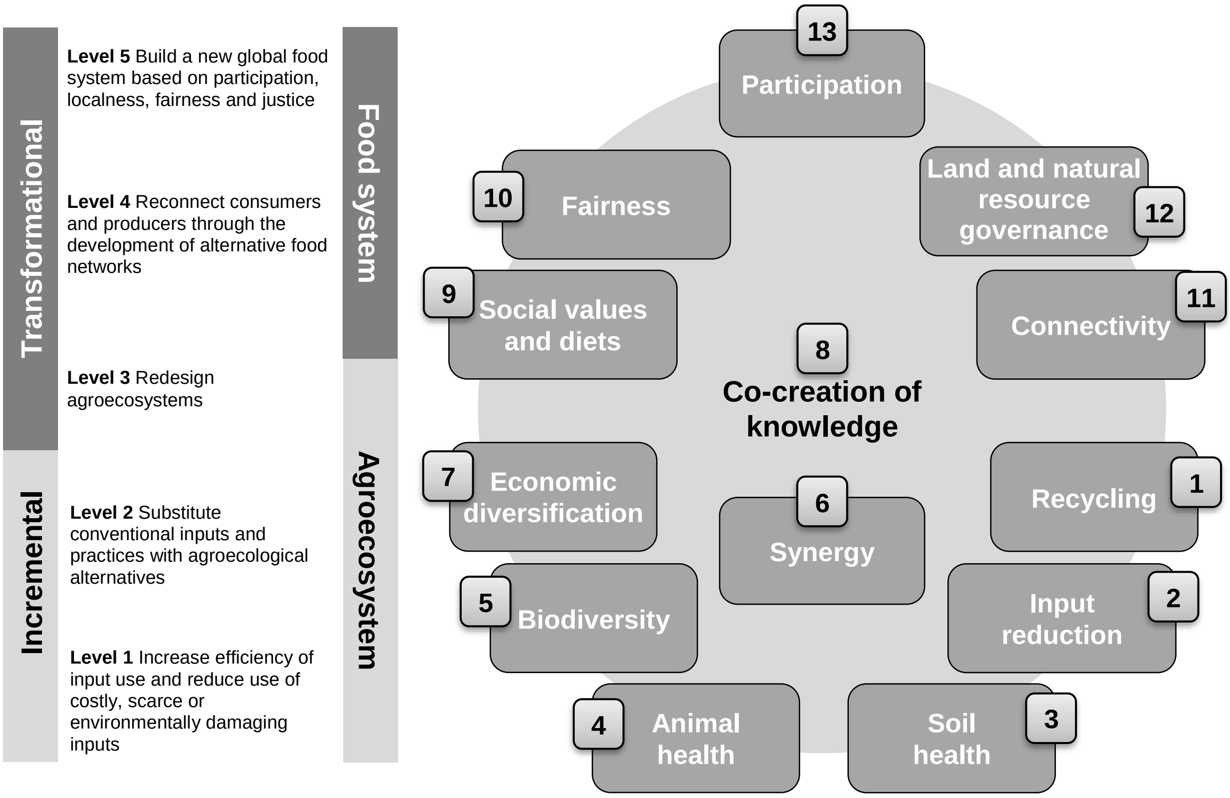
[21] See: https://biovallee.net/

[22] For more information on: French national strategy for ecological transition: https://www.ecologique-solidaire.gouv.fr/strategie-nationale-transition-ecologique-vers-developpement-durable-2015-2020

Figure 3 Five levels of transition towards SFSs and related principles of Agroecology



Source: transitions on the left hand side adapted from Gliessman (2007), with rounded boxes to the right representing the consolidated set of agroecological principles from Table 1.

2 INNOVATION FOR SUSTAINABLE FOOD SYSTEMS

Previous HLPE and other prominent reports have shown that ”business as usual” in agrifood systems is not an option and have highlighted the need for a major transformation of agriculture and food systems to tackle the multiple burdens of malnutrition, particularly for the most vulnerable and marginalized groups, and to contribute to the achievement of the 2030 Agenda (HLPE, 2014, 2016b, 2017b; IPES-Food, 2016; GloPan, 2016a, 2016b; FAO, 2017b).

As set out in the introduction of this report, transformation requires that both incremental transitions and more structural changes occur in a coordinated and integrated way in many parts of the food system; that is, in food production and supply chains, the food environment and on the consumption side (HLPE, 2017b). Given the huge diversity of food systems across and within countries, and the diversity of the challenges and constraints they face, actors in food systems will need to design adapted and context-specific transition pathways towards SFSs (HLPE, 2016, 2017b). These transition pathways may be grounded in very different narratives, leading to different sets of options for how change is realized.

In this chapter, after a concise presentation of innovation theories and related concepts, the main alternative approaches to innovation aiming at fostering transitions to SFS for FSN are identified and described in conjunction with Appendix 1. Common and unique principles employed by these approaches are then derived and assessed in relation to achieving FSN, resulting in the identification of a requirement to add to the operational principles for SFS and the pillars of FSN.

2.1 Innovation: concepts and definitions

Innovation is fundamental to bringing about the transformation of food systems because it encapsulates how people will do things differently in the future than they have in the past. Innovation has been clearly distinguished from research and invention (Schumpeter, 1939), so that “innovation is possible without anything we should identify as invention, and invention does not necessarily induce innovation”. The World Bank (2010) further explains this distinction by defining innovation as “the dissemination of something new in a given context, not as something new in absolute terms“, so “what is not disseminated and used is not an innovation”. FAO (2014b) goes further by stating that innovation includes “what is used and has resulted in substantial social and or economic benefit to the user” and the World Bank (2010) emphasizes that, from their standpoint, “innovation should ultimately benefit many people, including the poorest”.

This indicates that there is a need not only to develop new technologies, market mechanisms or institutional arrangements, but to close implementation gaps by making existing innovations more affordable, more accessible, especially for the poorest, and more adapted to different local conditions – whether political, social, cultural, economic or environmental (Wyckoff 2016; FAO, 2014b; HLPE, 2017a). Therefore, innovation should be seen not only as new technologies or ways of doing things, but rather as a dynamic learning process, that challenges and changes norms, practices and relationships and that generally requires interactions among many actors as well as new institutional arrangements (Nelson and Winter, 1982;; Smits, 2002; OECD and Eurostat, 2005; Vanloqueren and Baret, 2009; Struik et al., 2014; Loconto et al., 2017; Devaux et al., 2018; FAO 2018g). This innovation process requires not only technical changes but also social, market and institutional changes (Schumpeter, 1934; Smits ,2002; OECD and Eurostat, 2005; Klerkx and Leeuwis, 2009). In line with this school of thought, FAO (2016b) defined innovation, as “the process by which individuals or organizations master and implement the design and production of goods and services that are new to them, irrespective of whether they are new to their competitors, their country or the world”.

Recognizing the importance of interactions among many actors and institutions at different stages of this innovation process, Lundvall (1985), followed by many other authors, introduced the concept of *“innovation systems”*, defined as sets of interacting actors and institutions, or as human social networks behaving like biological systems, that determine the innovative performance of a community and constitute the resources (knowledge, human, financial) required for successful innovation to happen (Lundvall, ed, 1992; Freeman, 1988, 1995; Nelson, 1993; Patel and Pavitt, 1994; Metcalfe, 1995; OECD, 2001; World Bank, 2010; Coudel et al., eds, 2013). The World Bank (2012) defined innovation systems as “networks of organizations, enterprises and individuals focused on bringing new products, new processes and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance”. This notion can be applied within or across economic sectors, and at different scales, from local to national, regional and global. Innovation platforms are components of innovation systems deliberately set up to bring "together groups of individuals (who often represent organizations) with different backgrounds, expertise and interests – farmers, traders, food processors, researchers, government officials, and provide them with a space for learning, action and change" (World Bank, 2007a).

Adapting these reflections to the scope of this report, transitions towards SFSs for FSN, the HLPE suggests the following set of definitions for terms involving innovation (**Definition 3**).

It is well established that innovation has been a major engine for transformation of agriculture and food systems over the last century. Many reviews of innovation in agriculture refer back to Rogers (1962). In this influential book, Rogers characterized the different stages of innovation as successive phases involving different individuals: from innovators, early adopters and the late majority adopters, to laggards adverse to change. This characterization assumes that innovation – taken as the adoption of externally introduced technologies – is always progress, that innovations are technology-based, and that they disrupt past ways of conducting business (Joly, 2018).

Yet, it is increasingly recognized that many technological innovations in agriculture have generated significant negative externalities and that innovation in agriculture and food systems needs to address major social and environmental challenges to foster transitions towards SFSs that enhance FSN (Coudel *et al*., eds, 2013; Campbell *et al*., 2017; Frison *et al*., 2011; IPES-Food, 2016; Mahon *et al.,* 2017; Kremen and Merenlender, 2018; TEEB, 2018). Recent conceptualizations of innovation in agriculture place greater emphasis on social processes of innovation, on the fundamental role of local knowledge and adaptation, on the need for change to be built in continuity with the past and to be embedded in local circumstances (Smits, 2002; Joly, 2018; van der Veen, 2010; Faure *et al.*. 2018) and on the potential for innovation to foster transitions to SFSs for FSN within local communities, including for marginalized groups (Kilelu *et al.,* 2013; Elzen *et al*.. 2017). In a previous report, the HLPE (2018) asserted that agrifood innovation should be approached in a systemic and transdisciplinary way, involve multiple stakeholders and integrate their different and sometimes diverging perspectives and forms of knowledge. The Organisation for Economic Co-operation and Development (OECD) has produced a series of country-level studies on innovation, agricultural productivity and sustainability that explicitly highlight the need for comprehensive rural development policies to unleash the social benefits of innovation (e.g. OECD 2013; 2018).

Definition 3 Innovation that fosters transitions towards SFSs for FSN

- **Innovation** is used as a verb (to innovate) referring to the process by which individuals, communities or organizations generate changes in the design, production or recycling of goods and services, as well as changes in the surrounding institutional environment, that are new to their context and foster transitions towards SFSs for FSN. Innovation is also used as a noun to refer to the changes generated by this process. Innovation includes changes in practices, norms, markets and institutional arrangements, which may foster new networks of food production, processing, distribution and consumption that may challenge the *status quo*.
- **Innovation systems** are networks of organizations, communities, enterprises and individuals within which changes fostering transitions to SFS for FSN are generated and spread in the form of processes, forms of organization, dissemination of knowledge or bringing new products into use, together with the institutions and policies that affect their behaviour and performance.
- **Innovation platforms** are initiatives or efforts bringing together different stakeholders, with different views, experiences and interests, to create space for co-learning and collective action that supports transitions towards SFSs for FSN.

Innovations in agriculture and food systems are distinct from those in many other sectors, because ecological relationships and social interactions have a central role. The suitability of an agrifood innovation to local environmental and social conditions can be important, and thus local adaptations are integral to the innovation process. Food producers and those working in other parts of the food system have an intimate knowledge of the landscapes within which they work, acquired through their direct exposure and participation in the work process – a knowledge that is generally not codified, but passed along from farmer to farmer or practitioner to apprentice (van der Veen, 2010; Coudel *et al*., eds, 2013). This means that agricultural innovation systems often draw heavily on local knowledge and practice to ensure that they are context-specific and locally adapted to the socio-economic and ecological context at farm, community, agroecosystem and landscape levels (Coe *et al.*, 2019). In line with this, a number of people writing about agrifood innovation systems have recently put more emphasis on locally-generated innovation (Saravanan and Suchiradipta, 2017) and have paid greater attention to institutional innovation and capacity building through multi-stakeholder processes, with a strong focus on innovations emerging from the grassroots (Assefa *et al.,* 2009; Loconto *et al.*. 2017). An emphasis on local ownership of the innovation process does not underplay the importance of fundamental breakthroughs in technology, such as the advent of smart phones or genetic engineering, but does place emphasis on how and by whom they are used and incorporated within local contexts (Sinclair and Coe, 2019).

Agrifood innovations often aim at increasing food production and profit. Yet, many food producers, especially those with limited resources, may privilege a minimal risk rather than a maximal profit to ensure FSN for their family. Whatever the goal, understanding the distribution of risks and benefits associated with a given innovation is important to avoid potential negative impacts on FSN for marginalized or vulnerable people or communities (Glover and Poole, 2019).

Some people argue that large mechanized farms might be more efficient at producing food under cost constraints when available labour is a limiting factor (Jansen, 2015). However, where labour is more easily available than capital, such as in many parts of India and sub-Saharan Africa, labour-saving innovations requiring substantive investments might not be seen as desirable (Dorin, 2017). Labour-saving technologies such as herbicides might remove important sources of income and employment for low-income and marginalized rural workers, thereby threatening their FSN status. On the contrary, agroecological approaches, that may be more labour and knowledge intensive and that encourage experimentation, continuous learning and knowledge-sharing among farmers, could provide more opportunities for decent[23] and meaningful[24] work, especially for smallholders (Jansen, 2015; Timmermann and Félix, 2015; Bezner Kerr *et al.*, 2019; Deaconu *et al.*, 2019). Some authors consider that agroecology can lead to greater autonomy**,** a crucial characteristic of meaningful work, by encouraging farmers and farmworkers to become skilled and hence more difficult to replace (Timmermann and Félix, 2015; Deaconu *et al.,* 2019). Furthermore, the emphasis put by agroecology on localized economies with shorter value chains can lead to increased employment and business opportunities in rural areas that have been experiencing high levels of unemployment and migration (Jones *et al*., 2012; Pimbert, 2018b; Deaconu *et al.,* 2019).

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[23] The International Labour Organization (ILO) states that decent work sums up the aspirations of people in their working lives. It involves opportunities for work that is productive and delivers a fair income, security in the workplace and social protection for families, better prospects for personal development and social integration, freedom for people to express their concerns, organize and participate in decisions that affect their lives and equality of opportunity and treatment for all women and men. See: https://www.ilo.org/global/topics/decent-work/lang--en/index.htm

[24] Meaningful work is an emerging transdisciplinary concept arising from sociology, psychology and philosophy with applications in human resource management. It is often considered to have both objective and subjective components. The objective aspect refers to a moral obligation for employers / institutions to provide a context within which meaningful work is possible, including: free choice to enter, honest communication, fair and respectful treatment, intellectual challenge, considerable independence to determine work methods, democratic participation in decision-making, moral development, due process and justice, non-paternalism, and fair compensation (Michaelson, 2009). The subjective component refers to individual workers finding their work meaningful that has been described as arising when an individual perceives an authentic connection between their work and a broader transcendent life purpose beyond the self, referring either to when individuals perceive their work invokes the greater good in terms of societal or economic benefits, or is considered to be in the service of a ”higher power”, whether in a spiritual or religious sense, or within a non-theistic, humanist paradigm (Bailey and Madden, 2017).

In a number of respects, a “renewal of innovation” is under way (Joly, 2018), with a discourse that embraces: (i) democratization of innovation, promoting knowledge co-production and sharing within and among communities across distributed networks (von Hippel, 2004; Schot and Steinmueller 2016); (ii) responsible innovation, focused on issues of collective or public interest (HLPE, 2018), under inclusive and participatory forms of governance (von Schomberg, ed., 2011; Guston, 2006; Glover and Poole, 2019). A further aspect of this “renewal of innovation” is a new way to conceptualize innovation, called “innovation by withdrawal”, consisting of withdrawing from the dominant agrifood regime, substituting current technologies and practices with innovative alternatives that better support transitions towards SFSs (Goulet and Vinck, 2012). “Innovation by withdrawal” requires shifts in mentality for all actors involved (decision-makers, farmers, consumers), as well as progressive experimentation and adoption of alternative practices; it implies complex dynamics and happens over time (Goulet and Vinck, 2017). An illustration of this is farmers in France, who began to transition by withdrawing from the use of synthetic chemical fertilizers and adopting alternative organic sources, which rebuilt soil health and biological activity (Le Velly and Goulet, 2015). French policies aimed at reducing pesticide use did not get traction until effective alternatives, such as biological control of insect pests, began to be promoted (Aulagnier and Goulet, 2017). This shows the complex dynamic between landscape pressures, policy shifts, public perceptions and alternative niche experimentation by farmers. The dynamic took over a decade to generate transitions to more sustainable food systems. Research on agrifood transitions has revealed how novel practices in consumption, networking among producers and consumers, and other changes in daily social practices, have precipitated significant shifts towards SFS (Hinrichs, 2014), such as Fonte’s (2013) study of new Italian solidarity purchasing groups.

It is thus clear from the preceding sections that innovation in agriculture and food systems may be principally institutional, or may relate more to knowledge or to practice (Smits, 2002). These elements are connected to one another and may be internally generated within an innovation system, be externally introduced to it, or involve both these modalities in an adaptive process. This view of innovation in agriculture and food that recognizes that changes may be technological, related to knowledge about how and where technologies will be appropriate, or institutional in respect of how people within innovation systems interact, is consistent with the hardware, software and orgware categories of Klerkx and Leeuwis (2009) developed and applied within an innovation systems framework. Different innovative approaches fostering transitions to SFS for FSN, looked at in the following section, have tended to place emphasis on different modes of innovation.

In relation to the organizational aspects of innovation systems, there has been a shift of emphasis within international agricultural research, towards: (i) facilitation of farmer networking (Nelson *et al.*, 2016); (ii) the use of citizen science, involving recent developments in ICT to collate and share information involving large numbers of participating farmers (van Etten *et al.*, 2019 Dehnen-Schmutz *et al.*, 2016), although there is debate about how genuinely participatory some of these ICT-led innovations actually are, depending on the degree of control that farmers have over data and the nature of design choices and feedback mechanisms (Sinclair and Coe, 2019); and, (iii) a paradigm shift from research ”for” to research ’in” development, where research is embedded in development initiatives through “planned comparisons”[25] built into the scaling up of development initiatives (Coe *et al.*, 2014). These new developments all facilitate farmer participation, as has been successfully used in participatory varietal selection and plant breeding over several decades (Tiwari *et al.,* 2009; Bonneuil *et al.*, 2006; **Box 11**). A common feature of these approaches is that they use multi-stakeholder innovation platforms (Schut *et al.,* 2018). Such platforms are of interest because they generate innovations that support transitions that have impact at scale. For example, aggregation of village-level landcare groups in Kapchorwa, Uganda, create fora at landscape and regional scales capable of leveraging infrastructural change through influencing local and national government as well as private sector actors (Catacutan *et al.,* 2015).

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[25] A planned comparison refers to the deliberate measurement of the performance of different options (technologies, market interventions or policies) across a range of contexts (that may be ecological, economic or social). Planned comparisons embedded in development initiatives accelerate development impact where knowledge about the suitability of different options in different contexts is not perfect, which is generally the case. This works through facilitating co-learning with farmers about the circumstances in which different options work well or badly and contrasts with only offering each farmer what is considered to be a best bet in their specific context that restricts the opportunity of refining understanding about how context conditions the performance of options (Coe *et al*., 2017)

Box 11 Participatory plant breeding of sorghum in Burkina Faso[26]

Participatory plant breeding (PPB) actively involves producers at all stages of varietal development. In Burkina Faso, sorghum and pearl millet are the main staple foods in terms of area, covering more than 1.5 million ha. Yields of sorghum remain relatively low for smallholder farmers, at approximately 1 tonne/ ha, and although varieties have been developed with higher yield potential, there has been minimal adoption of these varieties.

In the 1990s, researchers from the Burkina Faso Institute of Environment and Agricultural Research (a government research institute - INERA), the Centre for International Cooperation in Agricultural Research for Development (a French public institution - CIRAD) and the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) began to use PPB methods to develop locally adapted and culturally appropriate varieties. Local farmers' organizations were involved in all steps of the decision-making process. The goal was to create new sorghum varieties that drew from the genetic diversity of populations of traditional varieties and improve them for local use using PPB methods.

Eight varieties developed through this PPB process were released and registered in the national catalogue between 2002 and 2018. These varieties showed a 7–30 percent increase in yields compared to traditional varieties. Impact assessment showed significant uptake and sales of these eight PPB varieties, and that farmers using these varieties increased their production of sorghum, their income and their FSN status. However, there were some trade-offs associated with use of the PPB varieties, such as an increased use of insecticide in storage. While in some regions the use of PPB varieties displaced traditional varieties, thereby reducing genetic diversity, in most areas farmers continued to grow local varieties along with PPB varieties. In addition, PPB methods improved farmers' technical knowledge of plant breeding as well as breeders' understanding of local farmers' needs and varietal requirements.

Source: Trouche *et al.* (2016).

Considering the distributional aspects of risks and benefits from innovation, these have simultaneously become a challenge, as for example is the case in nutrition (Glover and Poole, 2019).

2.2 Innovative approaches towards sustainable food systems for food security and nutrition

Innovation systems are value-laden, emerging within existing social orders, and thus reflecting the specific paradigms or world views therein (Joly, 2018). In this report, this is acknowledged by considering how innovation systems are impacted by taking different approaches to sustainable agriculture and food systems. Innovation is thus viewed in the context of the overall approach[27] being promoted. Building on the concepts and definitions developed in the previous section, and on the notions of transition and socio-technological regime developed in the introduction of this report, the HLPE suggest the following definition for innovative approaches to SFS for FSN (Definition 4).

Definition 4 Innovative approaches to SFSs for FSN

An innovative approach to SFSs for FSN is a well articulated and widely practised set of principles, practices and methods that is intended to foster transitions towards more sustainable food systems that enhance FSN and is set within an overarching philosophy and a strategic vision for the future.

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[26] See: https://www.cirad.fr/en/our-research/research-results/2016/participatory-sorghum-breeding-in-burkina-faso-production-of-new-varieties-with-and-for-the-farmers

[27] With the approach having been defined for the purposes of this report as "a set of principles, practices and methods embedded in an overriding philosophy, that is widely understood, promoted and practised with the intention of enhancing FSN" in the introduction.

Beyond agroecological approaches already illustrated in Chapter 1, the HLPE identified other innovative approaches aiming at fostering the transition towards SFSs that enhance FSN. These approaches, presented in more detail in **Appendix 1,** can be clustered under two main categories: (i) **sustainable intensification and related approaches** (including climate-smart agriculture, nutrition-sensitive agriculture and sustainable food value chains); and (ii) **agroecological and related approaches** (including organic agriculture, agroforestry and permaculture). Some literature confusingly includes agroecological approaches as forms of sustainable intensification despite them not being based on a premise of increased yield, which is what intensification implies (Pretty *et al*., 2018). Although very different in scope, rights-based approaches were also considered. This is in keeping with the report starting from a position of asserting the human right to food and also with the consideration that approaches that start from a premise of asserting rights are likely to produce different outcomes than those with a more technical focus on production. So the scope of approaches ranges from some that focus on agricultural production practices (lower levels of Gleismann's transition framework in **Figure 3**) and others that focus on how people interact with food systems rather than the particular practices applied (the higher levels of Gleismann's transition framework).

In this section, a comprehensive set of principles is derived from across all the approaches, to highlight convergence and divergence among them. To do this, principles were defined as statements that form the basis for a system of belief or reasoning that guides decisions and behaviour. They can be either **normative,** asserting values (e.g. food systems should be equitable), or **causative**, as in scientific usage, explaining relationships (e.g. more equitable food systems are likely to be more sustainable). In either case, to be useful in guiding decisions and actions, they need to be fully explicit. Despite the diversity of principles associated with the different approaches, a comprehensive set of principles was derived, most of which are common to several approaches (**Table 2**). The comprehensive set was developed by collating principles from across the different innovative approaches (**Table A, Appendix 1**) and then combining them where appropriate to develop a non-repetitive consolidated set (**Table 2**), as was previously done for agroecological principles in Chapter 1.

Principles have often been formulated in the literature on innovative approaches to SFS for FSN as normative statements, intending to provide explicit guidance for action (e.g. reduce or eliminate dependency on purchased inputs) or in ways that conflate normative and causative elements. They are often articulated within a narrative and are seldom stated in a way that would make them fully explicit outside the overall philosophy of the approach with which they are associated. This conflation of normative and causative elements and the inclusion of implicit interests or values, and in how principles are articulated, creates ambiguity in their interpretation and application. To avoid this, in **Table 2**, each principle is stated both as a normative statement and in terms of the causative relationships that are implied.

Table 2 Combined set of principles shaping transitions towards SFSs for FSN

Label	Normative statement	Causative statement
Regenerative production	Harness ecosystem services (ES) and natural processes in the productive process, optimizing the use of local renewable resources and minimizing negative externalities	The use of natural processes in agricultural and food systems rather than their substitution with alternatives (purchased inputs that often involve the use of fossil fuels in their manufacture) can enhance soil health (through managing soil organic matter and biological activity) thereby regenerating the capacity of land to provide ES.
Recycling and efficiency	Increase resource-use efficiency and reduce or eliminate dependency on purchased inputs	Deliberate management of agriculture and food systems that favours recycling, can reduce dependency on purchased inputs and risk or debt associated with their use, eliminates or reduces leakage of key resources (such as biomass and nutrients), and can enhance efficiency of resource use and resilience.
Animal health	Ensure animal health and welfare	Food systems that ensure animal health and welfare are more efficient, sustainable and socially acceptable.
Synergy	Enhance positive ecological interactions, integration and synergies between different components of agroecosystems	The deliberate management of interactions and synergies among functionally diverse components of agroecosystems enables the development of more efficient and resilient systems.

Diversity	Maintain and enhance diversity of species and genetic resources and maintain biodiversity in the agroecosystem over time and space, at field, farm and landscape scales.	The deliberate use of greater agrobiodiversity in agriculture and food systems than is typical in monoculture systems, can make them more ecologically and economically efficient and resilient and contribute to the development of healthier, diversified and seasonally (and culturally) appropriate diets.
Integration	Increase integration of system components throughout the food system to realize greater benefits and opportunities.	Deliberate management of interactions among components of food systems across scales can achieve greater integration, resulting in more efficient and sustainable performance throughout the food value chain.
Climate change adaptation and mitigation	Design and use agricultural practices that contribute to climate change adaptation and mitigation	Adoption of climate-smart agricultural practices can increase adaptation to climate change by targeting specific climate hazards and/or improving resilience of livelihoods at the same time as sequestering carbon and reducing emission of greenhouse gases.
Knowledge production and dissemination	Enhance co-creation and horizontal sharing of knowledge including local and scientific knowledge and innovation.	Experiential learning and knowledge-sharing among practitioners, and co-production of knowledge among multi-stakeholder networks, enhance its legitimacy and generates innovation adapted to the local context.
Cultural coherence	Build food systems based on culture, identity, social and gender equity, innovation and knowledge, that include healthy, diversified, seasonally and culturally appropriate diets of local communities and livelihoods	Food systems based on local culture and identity, along with being equitable and connecting producers and consumers, are likely to be sustainable. Reduction of meat, salt, sugar, ultra-processed foods and other unhealthy dietary practices in many diets can lead to better nutrition and health outcomes, as well as greater sustainability.
Human and social values	Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights	Implementing fair trade, fair employment, fair intellectual property (including with respect to genetic resources), access to natural resources and social and gender equity measures can contribute to creating and maintaining fair, dignified and robust livelihoods for all actors engaged in food systems.
Connectivity	Increase proximity and confidence of producers and consumers through fair and short distribution networks that embed food systems in local economies. Support alternative production and consumption models.	Better connecting producers and consumers (through shorter supply chains, re-embedding food systems in local economies, encouraging a circular economy) leads to greater trust and confidence among producers and consumers in the quality and safety of food and less waste along food chains
Governance	Recognize food as a basic human right; democratize the process of innovation and the control of food systems.	Recognizing food as a basic human right and increasing democratic control of food systems are key measures that have clear impacts on FSN. Institutions with numerical and substantive representation of all actors within food systems and their participation in decision-making are required for their equitable and democratic governance.
Empowerment	Recognize and support the needs and interests of key stakeholders in food systems (especially family farmers, smallholders and peasant food producers, and consumers).	Adopting measures to support interests of smallholder and family farmers as sustainable managers and guardians of natural and genetic resources counteracts market failures that favour economies of scale with negative externalities.
Participation	Encourage social organization and greater participation of food producers and consumers in how food systems operate with particular measures to include marginalized groups	Encouraging social organization and greater participation and decision-making of food producers and consumers will support decentralized governance and local adaptive management of food and agricultural systems. Democratization of innovations promotes ways that communities of people can share information and knowledge across distributed networks and contributes to innovation most appropriate for local contexts.

Based on the review of different approaches, principles can be used to characterize convergence and divergence. To do this, the principles in **Table 2** were amalgamated to generate a set of characteristics (**Table 3**), each of which is allocated four values, including two polar opposite positions (e.g. eliminate purchased inputs versus use them to intensify production) with two intermediate values in between, that together constitute a spectrum of positions along a continuum, indicated in the table by colour intensity.

Table 3 Innovative approaches to SFSs for FSN: a multi-dimensional continuum

Characteristic	Spectrum of values for each characteristic between two polar opposites
Regenerative production, recycling and efficiency	**Pole 1:** Eliminate external inputs, rely on only natural processes and have closed resource cycles
	Intermediate 1: Minimize purchased inputs, favour natural processes and try to close resource cycles
	Intermediate 2: Deliberately use purchased inputs to make efficient use of natural processes and resource cycles
	Pole 2: Use purchased inputs to intensify production per unit land while keeping leakage to a minimum
Biodiversity, synergy and integration	**Pole 1:** Deliberate management of biological diversity and interactions among components within production systems to enhance complementarity and achieve synergy, including between production and conservation objectives across field, farm and landscape scales (land sharing)
	Intermediate 1: Manage interactions among selected components within production systems without trying to maintain diversity beyond that necessary for production
	Intermediate 2: Neutral with respect to integrating or segregating components within production systems
	Pole 2: Intensify production on higher potential land thereby leaving other land for meeting conservation objectives (land sparing)
Economic diversification versus specialization	**Pole 1:** Strive for greater economic diversity of production systems
	Intermediate 1: Manage economic diversity of production systems around functional thresholds to maintain ecosystem services and economic resilience
	Intermediate 2: Neutral with respect to diversification or specialization
	Pole 2: Specialize in a few components within production systems to simplify management and supply market requirements
Climate adaptation and mitigation	**Pole 1:** Explicitly aim to design and use practices that contribute to climate change adaptation and mitigation
	Intermediate 1: Significant adaptation and mitigation co-benefits
	Intermediate 2: Significant adaptation or mitigation co-benefits
	Pole 2: No explicit attempt to contribute to climate change adaptation and mitigation
Knowledge generation and dissemination	**Pole 1:** Emphasizes support to local innovation and farmer-to-farmer knowledge exchange
	Intermediate 1: Emphasizes co-learning and the combination of local and global scientific knowledge
	Intermediate 2: Emphasizes widespread dissemination of innovations from participatory research
	Pole 2: Emphasizes widespread dissemination of innovation from state and privately-funded formal research
Human and social values: *Equity*	**Pole 1:** Recognizes inequality within food systems as a major problem constraining achievement of FSN
	Intermediate 1: Recognizes specific inequalities within food systems (e.g. in relation to gender) and tries to overcome them
	Intermediate 2: Does not focus on issues of equality
	Pole 2: Considers that market forces will iron out inequalities

Characteristic	Spectrum of values for each characteristic between two polar opposites
Human and social values: *Labour versus capital intensification*	Pole 1: Emphasis on labour intensification, fairness and dignity of work for all
	Intermediate 1: Emphasis on labour productivity while retaining smallholder farming
	Intermediate 2: Neutral on intensification dimensions
	Pole 2: Emphasis on capital intensification
Connectivity (value chains/circular economies) versus globalization	**Pole 1** Emphasis on local markets, connectivity of producers and consumers, circular economy
	Intermediate 1: Blended market approach combining access to national markets where appropriate with stimulating function of local markets
	Intermediate 2: Neutral with respect to marketing or value chain structure
	Pole 2: Emphasis on efficiency of large markets and global value chains
Governance: rights, democratization and participation	**Pole 1:** Starts by asserting basic rights and works on from that to how food systems should be transformed; strives for greater agency – i.e. participation of civil society in decision-making about how food is produced, processed, stored, transported and consumed
	Intermediate 1: Acknowledges that rights, including rights to accurate information, are an important part of food system transformation and includes consideration of them
	Intermediate 2: Neutral regarding rights
	Pole 2: Does not explicitly recognize rights as fundamental to food security and nutrition; participation is shaped through market forces

When the characteristics and spectra of values in **Table 3** are tabulated with respect to the innovative approaches (**Table 4**), clear patterns emerge among the two major categories of approach and the individual approaches within each category. The characteristics in **Table 3** are allocated to the operational principle for SFSs to which they most clearly contribute (resource efficiency, resilience and social equity/responsibility), notwithstanding the interlinkages and synergies among them.

Sustainable intensification and related approaches focus mainly on aspects analogous to the first level of Gliessman's agroecological transitions presented in Chapter 1 **(Figure 3).** They privilege technological and productivity-oriented innovations in order to improve resource efficiency while reducing the negative environmental and health impacts of current food systems (Béné *et al.*, 2019; Foley *et al.*, 2011; Haddad *et al.,* 2016; Tilman and Clark, 2014; Bernard and Lux, 2017). They start from a premise that yield per unit of land needs to increase (Pretty *et al*., 2018), which is what the intensification part of the "sustainable intensification" label implies. Whether or not any particular form of sustainable intensification could be considered part of an agroecological transition will depend on whether other key agroecological principles, such as co-creation of knowledge, minimizing toxic inputs and maintaining agrobiodiversity, are included.

In contrast, agroecological and related approaches, already described in Chapter 1, aim to be more transformative. They aim, at their most ambitious, to redesign the whole food system (highest level of Gliessman's transitions, **Figure 3**). They embrace more territorially-specific visions, taking into account environmental, health, social and cultural conditions in a given location (Francis *et al.,* 2003; Gliessman, 2007; Wezel and Soldat, 2009; Wezel and David, 2012; Méndez *et al.,* 2013; Wezel *et al*., 2018a). They give a central place to the social, cultural and political dimensions of transitions towards SFSs, to power dynamics and governance issues. They address not only ecological and health impacts of food systems but also power asymmetries and socio-economic inequalities (De Schutter, 2010; IPES-Food, 2016; Rosset and Martínez-Torres, 2012; Rosset *et al.*, 2011; Bernard and Lux, 2017; Wezel *et al*., 2018b, 2018b). As such, they are embedded in a human rights-based framework (e.g. Misra, 2018).

It should be noted that there has been limited focus in agroecological approaches on the economic implications of labour-intensive methods, consumer preferences and the dynamics of demographic change, including migration and conflict impacts. Agroecological approaches place emphasis on addressing governance, sociocultural and knowledge factors to promote environmentally-friendly practices (Rosset *et al.*, 2011; Bernard and Lux, 2017; Wezel *et al*., 2018a, 2018b). Key barriers to transitions from an agroecological perspective include power imbalances within the retail and input agrifood industry, which lead to unequal access to knowledge, resources and unequal governance of food systems, and subsequent ecological, health and social impacts (IPES-Food, 2016; Bernard and Lux, 2017).

The two categories of innovative approaches (sustainable intensification and agroecological) are thus grounded in very different visions of the future of food systems, in terms of what the main characteristics of a SFS should be, and on very different strategies for how to implement transitions towards more sustainable food systems. Hence, they reflect diverging narratives on the priorities for transition, on the directions that social and technological innovation should take, and hence on the tools, practices and technologies that can contribute, or not, to facilitate transitions towards SFSs. They also overlap in many respects and so there are commonalities and complementarities among them.

Table 4 Comparison of different innovative approaches towards SFSs for FSN

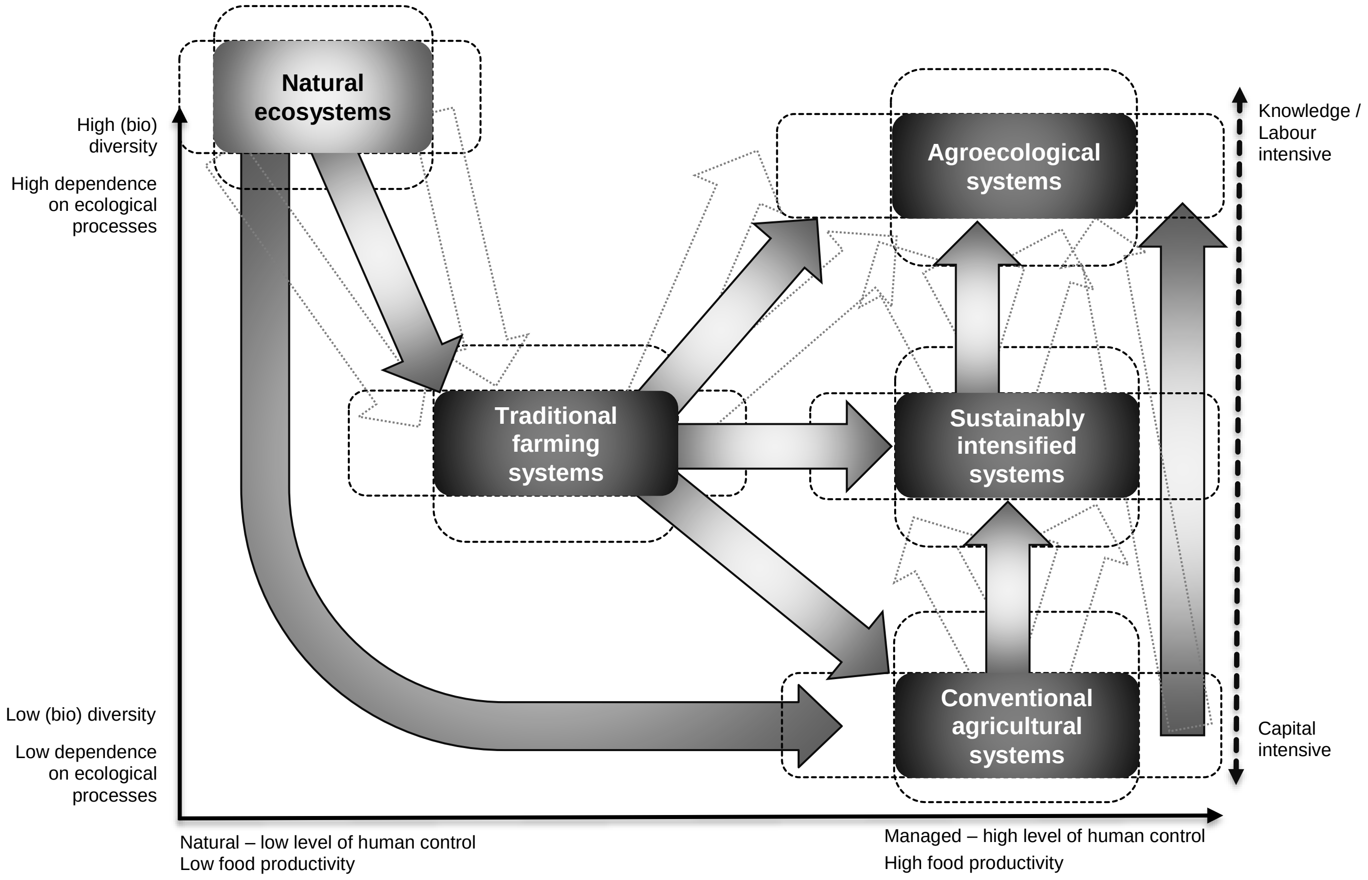
Characteristic	Agroecological and related approaches					Sustainable intensification and related approaches			
	Agroecology	Organic Agriculture	Agroforestry	Permaculture	Food sovereignty	Sustainable intensification	Climate smart agriculture	Nutrition sensitive agriculture	Sustainable food value chains
Resource efficiency									
Regenerative production, recycling and efficiency	█	▓	▓	█	█	░	░	No evidence	No evidence
Biodiversity, synergy and integration	█	█	█	█	▒	░	░	▓	▒
Resilience									
Economic diversification versus specialisation	█	▓	▓	▓	█	░	░	▒	▓
Climate adaptation and mitigation	▒	▒	▓	▓	░	▒	█	░	░
Social equity/responsibility									
Knowledge generation and technology transfer	█	▓	▓	▓	█	░	▒	░	░
Human and social values: *Equity*	█	▓	▓	▓	█	░	░	▒	▒
Human and social values: *Labour versus capital intensification*	█	▓	▓	█	█	░	░	▒	▒
Connectivity (value chains/circular economies) versus globalization	█	▓	▓	█	█	░	░	▒	▓
Governance: rights, democratization and participation	█	▓	▓	▓	█	░	░	░	░

Note: The table uses the characteristics as defined in previous **Table 3**. The grey-scale intensity of the cells represents the evaluation of the HLPE based on the evidence about the approaches set out in this chapter and in Appendix 1. This gradient does not convey any value judgement, but simply locates where along a defined continuum each approach lies. The methodology is explicit and could be repeated by others or against different evidence bases resulting in different grey-scale intensity in the different cells.

As highlighted in Chapter 1, there are no clear consensual boundaries distinguishing what is agroecological and what is not. Similarly, in addition to clear differences among the approaches, there are overlaps, and no single approach embraces all of the principles outlined in **Table 1**. It is important to appreciate that the clustering of approaches into two main categories suggested above is not meant to hide the diversity of approaches that may be followed in the same territory or even on the same farm. Rather than setting up a binary opposition between the two categories, the intention is to point to the diversity of possible transition pathways that there is, from a range of different starting points, aiming towards differently configured sustainable farming and food systems of the future, built on different values and focusing on different aspects.

This concept of multiple transition pathways is depicted in **Figure 4,** which shows different trajectories for transitions in multi-dimensional space with dotted lines indicating variability in starting points and uncertainty of the progress of transitions. This emphasizes the context-specific nature of transitions and the choices involved in taking different transition pathways that intensify with respect to different factors of production. It focuses on different agricultural practices rather than whole food systems that are considered further in the next section.

Figure 4 Multiple transition pathways of agricultural systems



Note: The figure shows multiple trajectories from natural ecosystems to traditional farming systems, then to the predominant conventional (largely monocultural) agricultural systems and from these to innovative sustainably intensified and agroecological systems. The dotted lines around nodes indicate variability in status of different types of system and dotted arrows indicate variable and multiple transition pathways between states. Grey arrows indicate predominant transitions.

Source: Adapted from Griffon (2013) and Hainzelin (2016).

2.3 Transition towards sustainable food systems: emerging concepts

The analysis of approaches set out in the previous sections indicates a need to expand both the three operational principles for SFSs (improve resource efficiency, strengthen resilience and secure social equity/responsibility; HLPE, 2016) and the four pillars of FSN (availability, access, utilization and stability) in order to capture key ways in which agroecological approaches affect the sustainability of food systems. The depiction of transitions in **Figure 4**, while useful, focuses on contrasts in the nature of production systems, but consumption patterns and what happens to food from the farm gate to being eaten are of equal importance to development of SFSs for FSN. HLPE recognizes two key areas that require greater attention, encapsulated in the concept of ecological footprint to extend the framework of operational principles of SFS and the concept of agency to expand the four pillars of FSN. Each of these is introduced below and then taken up in greater operational detail in Chapter 4.

2.3.1 Ecological footprint

Agroecological approaches led to the idea that some critical dimensions of food-system performance needed to be further addressed: first, the need to factor in consumption as well as production; and second the finding that, if degradation and restoration are factored into accounting, it goes beyond the concept of "resource efficiency" to capture the effect of current production on future capacity to produce. If this could be achieved, it would significantly expand the operational principles of SFS.

Minimizing environmental impacts has sometimes been included as part of the operational principle of improving resource efficiency (HLPE, 2016). However, as illustrated in Chapter 1 and in previous sections, agroecological and related approaches (including agroforestry, permaculture and organic agriculture) focus on the application of ecological concepts and principles to the design and management of SFSs, harnessing natural processes, and creating beneficial biological interactions and synergies among the different components of agroecosystems (crops, animals, trees, soil and water). Given this focus, it is important to consider more deeply the environmental externalities, both positive and negative, of agriculture and food systems related not only to how food is produced but also to how much is consumed and how it is processed, transported and sold. Therefore, the HLPE suggests that there is scope to pay more attention to the concept of ecological footprint (**Definition 5**) and to consider adding this as a fourth operational principle for SFSs to **improve ecological footprint** (see **Figure 5**).

Definition 5 Ecological footprint of food systems

Ecological footprint of food systems expresses the impact of food consumed by a defined group of people (an individual, a village, a city, a country or the whole global population), measured in terms of the area of biologically productive land and water required to produce the food consumed and to assimilate the wastes generated (adapted from Wackernagel and Rees, 1996).

As a metric for evaluating the performance of agriculture and food systems, both its absolute value and the change in the ecological footprint over time are important (Wiedmann and Barrett, 2010). If the absolute value of the ecological footprint is higher than the land and water resources available at that time to the people concerned, the system is not sustainable. The change in footprint shows whether a system is improving or degrading over time and, therefore, how transitions are performing (Lin *et al.,* 2018).

The trajectory of ecological footprint should be affected by changes both in production and consumption patterns, so that increases in efficiency or regenerative processes, such as land restoration, will improve the ecological footprint over time for a given level of consumption, while less efficient processes or land degradation will result in more land being required; but the current global accounting framework does not take restoration or degradation into account because of a lack of available comparable data (Blomqvist *et al.,* 2013; Rees and Wackenagel, 2013) – an issue that is further discussed in Chapter 4.

The concept of ecological footprint has been effective in communicating issues around sustainability but subject to criticism, especially regarding its usefulness in guiding policy decisions and the effect of aggregating different aspects in a single indicator, resulting in calculation methods continuing to be developed, contested and refined (Fiala, 2008; Kitzes *et al*., 2009; Wiedmann and Barrett, 2010). The challenge is to develop ecological footprint accounting to encompass a multi-dimensional indicator framework that relates consumption and production, taking account of regenerative or degradative effects of agriculture.

2.3.2 Agency

The different dimensions of FSN are linked to equity, governance and power dynamics within the agrifood system at multiple scales (Sen, 1981; De Schutter, 2014; Bellows *et al*., eds, 2016). The present analysis of approaches, concurring with increasing evidence since the four pillars of FSN were first articulated, indicates a need for more explicit ways of addressing critical aspects of human rights and reinforcement of community capacities, power and control to make progress in achieving FSN for all (De Schutter, 2014; Smith and Haddad, 2015). In that context, the emerging concept of agency (**Definition 6)** is gaining traction in the international discourse on FSN.

Definition 6 Agency

Agency denotes the capacity of individuals or communities to define their desired food systems and nutritional outcomes, and to take action and make strategic life choices in securing these. This requires sociopolitical systems wherein policies and practices may be brought forth by the will of citizens and be reflected in governance structures to enable the achievement of FSN for all. (Adapted from Ganges, 2006; Chappell, 2018.)

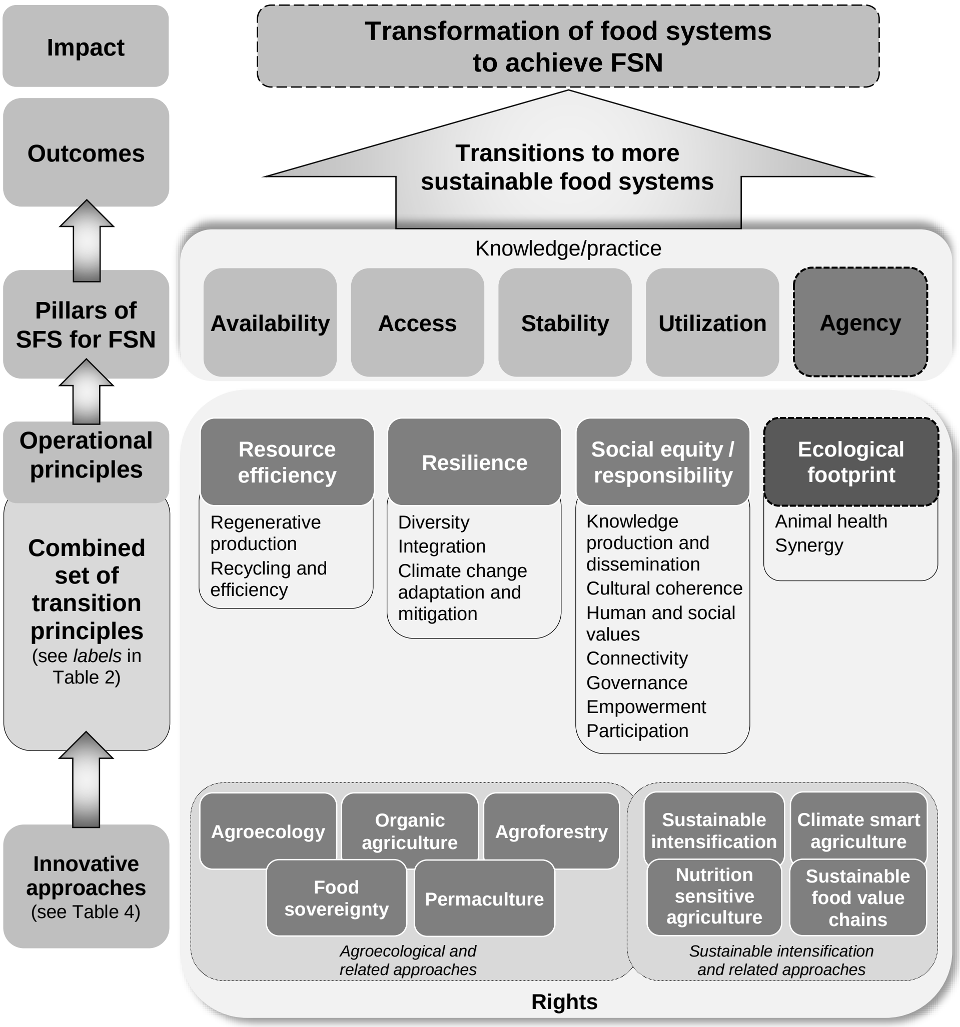
Based on the scientific literature on empowerment, access has two critical dimensions: the first is asset-based, currently emphasized and well covered under access as the second FSN pillar; the second focuses on institution-based opportunity structures (Chomba *et al.,* 2016) and refers to the prevailing institutional environment and different people's ability to access and influence it. This latter dimension has a long tradition going back to Amatya Sen's (1981) seminal work on hunger, and is essentially concerned with democratization of food systems: who controls, decides and benefits from agrifood systems, and how to ensure that people have access to critical public goods such as water, land, seeds, forests and knowledge that are essential for agricultural production (von Braun and Birner, 2017). Both utilization and stability are also influenced by democratic governance of food systems, including impacts on health care, the effects of rising concentration in the input and retail sectors of agriculture and food, access to resources, international trade, conflict, discrimination and other political, social and economic conditions that affect people's ability to have adequate and nutritious food (De Schutter, 2014; Ottersen *et al*., 2014; Ayala and Meier, 2017). Gender equality at multiple scales also shapes people's access and control over resources and in turn FSN (Bellows *et al*., 2015, 2016).

Respecting the evolving understanding of what is needed to make enduring impacts on food insecurity and inadequate nutrition, HLPE advises consideration of adding a fifth pillar of FSN on "**agency**" in keeping with its emergence as a critical dimension of FSN (Rocha, 2009, Chappell, 2018). Achieving agency implies the need for access to accurate information, the right to such information and to other aspects of food security, as well as the ability to secure such rights, including access and control over the resources required for production, harvesting and preparation of foods (Chappell, 2018).

2.3.3 A framework for harnessing innovative approaches to achieve food security and nutrition outcomes

The different approaches outlined in this report all identify particular trajectories and opportunities for change that may contribute to designing a food system transition framework with the view to progress towards SFSs for FSN and the realization of the right to adequate food. The framework presented in **Figure 5** shows how approaches, principles, FSN pillars, outcomes and impact can be brought together to explore the implementation of different innovative approaches for transformative change of food systems. Unique aspects included in this framework are the incorporation of the ecological footprint concept and the inclusion of agency as an essential component of FSN.

Figure 5 Framework for innovative approaches to SFSs for FSN



Note: The framework shows how different innovative approaches to SFS for FSN influence the operational principles of SFS and pillars of FSN with expansions of these to include ecological footprint and agency.

The characterization and analysis of different approaches highlights that structural transformations in the sociotechnical regime and in policy and institutional environment, on the one hand, and transition pathways, including technology, on the other, are intimately interacting to mainstream change.

As a consequence, the social innovation and political-economic transitions that are needed to bring about the ecological, human health and socio-economic changes for transforming food systems must contend with numerous barriers, “lock-ins” and general resistance to change from the *status quo*. Chapter 3 of this report looks at how this conceptual framework can be mobilized when examining controversial issues and how they can be harnessed and surmounted to foster transitions to sustainable food systems.

3 DIVERGING PERSPECTIVES ON HOW TO ACHIEVE FOOD SYSTEM TRANSFORMATION

Identifying the key drivers of, and structural challenges to, transitioning to SFSs for FSN through agroecological and other innovative approaches is critical for understanding potential constraints that may become barriers to achieving transitions and ways to overcome them (OECD and Eurostat, 2005; IPES-Food, 2016).

A series of key drivers that are likely to hamper or slow-down innovations that support transitions to SFS for FSN have been identified (OECD and Eurostat, 2005; Clapp and Fughs, 2009; Vanloqueren and Baret, 2009; World Bank, 2010; Smith and Haddad, 2015; Avelino and Wittmayer, 2016; FAO, 2016b; IPES-Food, 2016, 2017b; IFAD, 2017; Wezel *et al.,* 2018a). They can be grouped into five main areas as follows.

1. ***Governance factors***: short-term and compartmentalized political systems; trade policies, legal frameworks and incentives which reinforce unsustainable food systems, food insecurity and malnutrition; lack of democracy in food systems and power imbalances that reinforce the *status quo*.
2. ***Economic factors***: lock-in path dependencies; increased corporate consolidation; declining rural employment; rising inequalities; limited market options for sustainable food products; high costs; uncertainty or perceived risks associated with innovation for sustainable transitions.
3. ***Resource factors***: low soil fertility, technological gaps, productivity gaps, lack of available labour, inadequate access to land, water, seeds, genetic resources, credit and information.
4. ***Social and cultural factors***: dietary changes; producer and consumer expectations; dominant discourses; social capital, sociocultural norms and practices and food preferences.
5. ***Knowledge factors***: research metrics that do not address environmental, health or social externalities, skewed public investments in research and development, lack of knowledge or capacity in innovations that support SFS, lack of information on existing or new technologies as well as knowledge that allows decisions to be made about the value of market options for various players along the supply chains.

These drivers overlap and interact to constrain innovation for transitions to SFS and FSN acting on five key dimensions of transitions: livelihoods; FSN in human health; ecological footprint; democratic governance; and knowledge and cultural diversity – all of which are underpinned by rights as a fundamental basis (**Figure 6**). For example, governance, economic, resource, social and cultural drivers influence access to knowledge. The six controversial issues discussed in this chapter (3.1 to 3.6) are positioned in relation to the dimensions with which they are most closely associated.

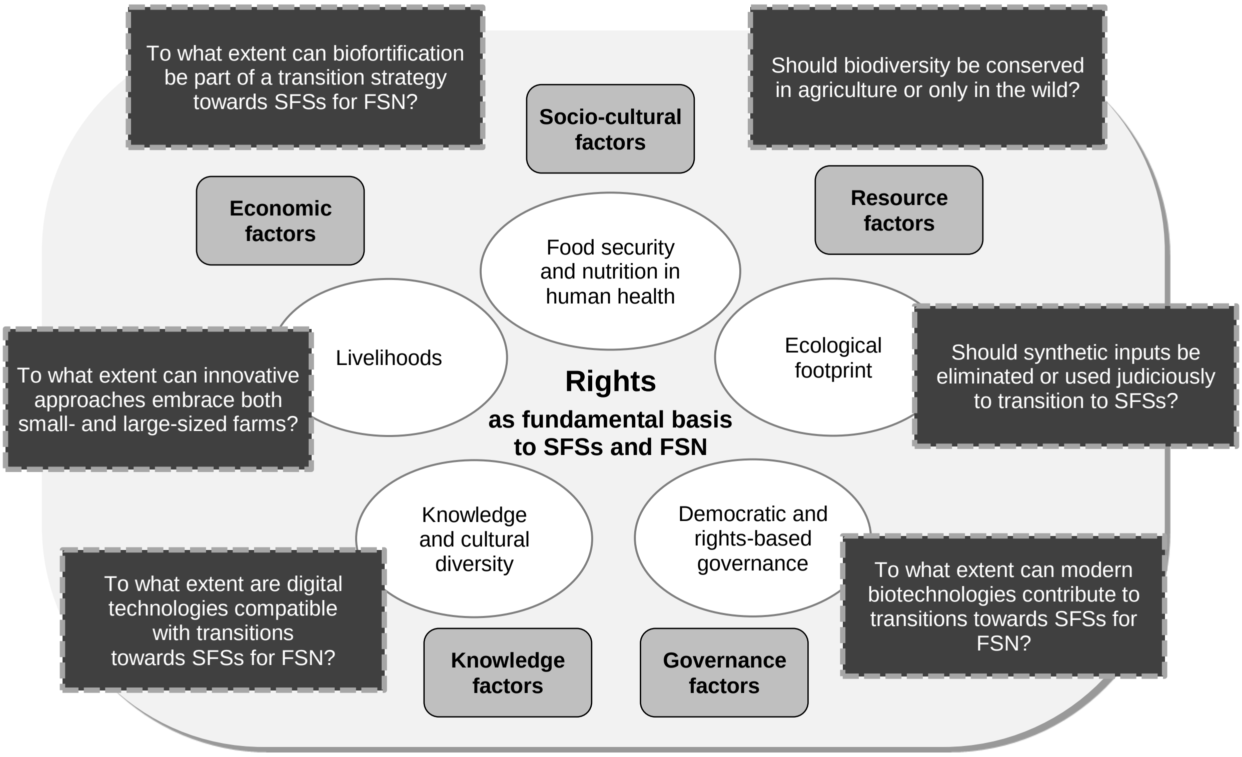
While there is some agreement about key drivers and challenges among the innovation approaches reviewed in Chapter 2 of this report, there are some notable differences related to the power dynamics around who practices and benefits from particular innovations. There are also debates about whether adopting certain innovative approaches might undermine political, social and ecological drivers of other innovations or engender further constraints (Caron *et al.*, 2018). This generates some key areas of controversy around innovations that enable transitions to a healthy planet, people and communities.

The approaches to innovation outlined in Chapter 2 differ with respect to which of the groups of drivers are emphasized and addressed, alongside many shared perspectives. Sustainable intensification approaches tend to emphasize economic and resource drivers, with a focus on productivity and technological solutions (Bernard and Lux, 2017) along with sustainable use of natural resources. The main issues from this perspective are population growth, technological investments, poorly functioning markets and consumer preferences. International trade from this perspective can cushion producers from shocks. Agroecological approaches place more emphasis on addressing governance, sociocultural and knowledge drivers and environmentally-friendly practices, without compromising on productivity (Rosset *et al.*, 2011; Bernard and Lux, 2017; Wezel *et al*., 2018b, 2018b). Key barriers from an agroecological perspective include power imbalances within the retail and input agrifood industry, as well as inappropriate market structures, which lead to unequal access to knowledge, resources and governance over the food and trade systems, and subsequent ecological, health and social impacts (IPES-Food, 2016; Bernard and Lux, 2017).

Sustainable intensification approaches have placed more emphasis on agricultural productivity and on economic, resources and some knowledge barriers to innovation creating an urgent need in many contexts to address social, cultural and governance drivers (Gomiero *et al.*, 2011). They focus on sustainable management of renewable resources and inputs, resource efficiency to increase profit margins and improved technologies, including improved crop and livestock varieties and policies to promote such change. The focus on productivity and technology in sustainable intensification has sometimes been associated with a lack of a fully integrated approach that fosters sustainable transitions across the whole agrifood system covering ecological, social, political and health dimensions (Horton *et al*., 2016) and variable involvement of people and communities who drive change through informed collaborative decision-making and a more democratized and productive agrifood system. Agroecological approaches have increasingly embraced more territorially-specific visions of whole food systems (**Box 12**), taking into account environmental, health and social drivers. including valuing women's knowledge and upholding their rights in a given place (Francis *et al.,* 2003; Gliessman, 2007; Wezel and Soldat, 2009; Wezel and David, 2012; Méndez *et al.,* 2013; Wezel *et al*., 2018a). There has been limited focus in agroecological approaches on the economic implications of labour-intensive methods, consumer preferences and the dynamics of demographic change, including migration and conflict impacts.

In this chapter, six controversial issues are discussed that highlight the differences among innovation approaches in how they effect transitions. Clarifying the nature and extent of controversy for each of these issues – who practices and promotes them, what issues related to SFS and FSN they address, and the evidence upon which they rest – is useful in understanding the potential contributions that agroecological and other innovative approaches can make to enhancing SFS for FSN, where uncertainties or fundamental disagreements remain and what can be done to remove structural barriers and enable transitions to SFS for FSN.

Figure 6 Dimensions of food systems, barriers to transitions towards SFSs and controversial issues



Note: Dimensions of transitions are shown in ellipses, groups of drivers acting as barriers in rounded rectangles and illustrative controversial issues discussed in the following sections of this chapter, posed as questions, in sharp cornered rectangles.

These core differences among the approaches lay the groundwork for exploring the six controversial issues set out in **Figure 6** and addressed, one by one, in the following sections of this chapter. These six controversial issues reflect important contemporary debates. Yet, they do not capture all areas of contestation. They were selected to illustrate the diversity of drivers and the different dimensions of SFSs. These sections build upon previous HLPE reports that considered divergent views and framed controversial issues in relation to nutrition, small-scale agriculture, sustainable agriculture for development, food waste and upon the recommendations that were formulated in those reports (HLPE, 2013b, 2014, 2016, 2017b, 2018).

Box 12 ***Fome Zero*: connecting public food procurement programmes to sustainable rural development in Brazil**[28]

Brazil has progressively emerged as a major agricultural producer over the past few years; a net importer of agricultural products in the 1970s, the country now ranks among the world’s five largest agricultural producers and exporters. The emergence of Brazil as a major agricultural producer is the result of a strong policy aimed at supporting the agriculture sector, active civil society and social movement mobilization, and based on a wide range of measures. The main programmes implemented as part of this “Zero Hunger Strategy” aimed at facilitating access to proper nutrition, supporting agriculture, promoting income-generating activities and encouraging social mobilization. As part of this strategy, Brazil has implemented a wide range of measures – providing storage facilities, family allowances, easy access to credit and insurance, price regulation, professional training programmes and additional programmes aimed at reinforcing control systems and bodies in charge of monitoring the nutritional quality of food.

Between 2000 and 2006, a mixture of financial support to farming families and community projects such as school feeding has reduced malnutrition among children under the age of two from 12.7 percent to 3.5 percent. The strategy has also contributed to a 47 percent drop in infant mortality.

In north-eastern Brazil, the poorest area of the country, overall levels of malnutrition fell from 17.9 percent in 1996 to 6.6 percent in 2005. Stunting, the physical and mental damage that results from child malnutrition, also fell by half during that period, from 13.5 percent to 6.8 percent.

An important part of the Zero Hunger Strategy is the *Bolsa Familia* programme – cash stipends that help families weather poverty with income that also helps boost local economies. In the Brazilian heartland, the programme has helped many farm labourers become independent farmers with land of their own. Small-scale producers were linked with schools for the supply of fresh nutritious meals. The link was acknowledged important for the success of the Zero Hunger Strategy.

The success of the strategy is evidenced by other nations either replicating it or aspiring to adopt it in some way or another, including Antigua and Barbuda, Argentina, Australia, Bangladesh, Cambodia, China, Germany, Ghana, India, Kenya, Malawi, Pakistan, Zambia and Zimbabwe.

Despite the recent advances in public policies to promote food security. such as the well-established Zero Hunger Programme, which significantly reduced the country's hunger and was a source of inspiration for various initiatives around the world, there is still some malnutrition. According to the International Food Policy Research Institute (IFPRI), it is estimated that approximately 1.6 percent of the Brazilian population is still hungry (IFPRI, 2016) – more than 3 million people – and this situation is likely to worsen as a result of the economic crisis affecting the country (BBC, 2016). The possible reversal in social security policies including Zero Hunger may also change the level of food insecurity. The importance of social movements and civil society working with governments to address malnutrition, and the influence of political priorities in addressing malnutrition, are highlighted by this case study.

Source: Wittman and Blesh (2017).

3.1 To what extent can innovative approaches embrace both small- and large-sized farms?

The issue of farm size or scale of operation tends to arise with an emphasis on comparative advantage and meeting the food needs of a growing population through sustainable intensification

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[28] See also: http://www.fao.org/3/a-i3023e.pdf; http://www.fao.org/docrep/016/i3023e/i3023e00.htm; http://www.un.org/en/zerohunger/pdfs/Zero%20Hunger%20country%20actions%20Dec_2015.pdf; https://www.wfp.org/stories/brazil-shows-world-how-beat-hunger-says-wfp-head; https://www.oxfam.org/sites/www.oxfam.org/files/cs-fighting-hunger-brazil-090611-en.pdf

(Godfray *et al*., 2010) rather than in relation to access to knowledge, resources and control over the food system as underlying causes of food insecurity and malnutrition, which are often preoccupations in agroecological approaches (Loos *et al*., 2014).

Farm size is relative, and context-specific, based on historical, social, economic and ecological conditions: for instance, a farm called "small" in the United States of America can be considered as "large" in many African countries. Family farms, however, both in developed and developing countries, may share common features with regard to innovation, agrobiodiversity, intensification strategies and links to territories (Sourisseau, 2014).

3.1.1 Revisiting economies of scale

There has been a dominant narrative that farms in developing countries are too small to justify investments and that "economies of scale" in agricultural management make larger farms more efficient and productive (Hayami and Ruttan, 1985). However, greater economic efficiency at larger sizes could not be found in the United States of America where there has been consolidation of farms (Kislev and Willis, 1986). Cost curves may decrease initially as farm operations grow in size, but these economies dissipate sooner than generally perceived. Large-scale production systems favoured by the economy of scale argument often involve negative impacts on the environment and on rural communities (Duffy, 2009). An inverse relationship between farm size and measured productivity has often been documented with small farms shown to be highly productive in terms of their output per unit of land area, even if productivity per unit of labour is low or variable (Barrett *et al.,* 2010; Gollin, 2018). Context is critical when considering the contribution of potential economies of scale to FSN. As highlighted in Chapter 2, transition pathways will differ depending on the extent to which labour, land or capital are limiting (Dorin, 2017).

Simple yield measurements in small, diverse farming systems may not adequately reflect actual productivity. The "polycultures" that characterize many smallholder farms in parts of sub-Saharan Africa, Latin America and Asia, with grains, fruit, vegetables, animal fodder, trees and livestock cultivated in the same field, generally yield in aggregate more than monocultures, even if the yield of each single crop is below that in monoculture on larger farms. From 20 to 60 percent higher yields have been estimated when all crops are taken into account (Badgley *et al*., 2007). In fact, diversified polyculture systems might be more efficient than monocultures because they suppress weeds by occupying all available growing space, reduce losses due to pests and diseases and, by associating multiple species with different resource capture profiles, make more efficient use of water and light through exploiting niche differentiation (Francis, 1986; Anderson and Sinclair, 1993; Badgley *et al.,* 2007; Cardinale *et al.,* 2007; Prieto *et al.,* 2015). Some recent reviews have shown conventional single-crop systems to have higher yields (from 8 to 20 percent) of individual crops compared to diversified, organic systems in some contexts (Ponisio *et al.,* 2015; Reganold and Wachter, 2016). However, two global reviews found that diversified systems outperformed conventional systems in developing country contexts by as much as 80 percent (Pretty *et al.,* 2006; Badgley *et al.,* 2007). Given the limited amount of public investment in agroecological approaches highlighted in section 1.4.5, and considering that most modern crop varieties have been bred and selected under high input use, these findings suggest a high potential to sustainably address yield gaps through greater investment in agroecological research.

Farm size and landscape diversity are linked to the capacity of farming systems to work effectively with biological and ecological processes, such as recycling of biomass and provision of pest control and pollination services. For example, smallholder farmers, cultivating less than 2 ha, have been shown to be able to increase yields by a median of 24 percent by promoting greater visitation of pollinators to their crops (Garibaldi *et al.,* 2016); their already high levels of diversity support populations of pollinators that can be enhanced by relatively simple measures. These are options that are not so readily available to larger-scale farmers with larger fields (Garibaldi *et al.,* 2016). Ecological pest control works through restoring the balance between pests and their natural enemies and barriers to movement through the use of cultural techniques, promotion of on-farm diversity, choice of appropriate varieties and the introduction of natural enemies (see **Box 5**). These measures, which require intricate on-farm knowledge and precise work organization, can most effectively be implemented at relatively smaller scales of operation. Sustaining soil health and fertility, using crop rotations and intercrops, cover crops and application of compost and organic manure, are more common where farm sizes are relatively small due to greater labour intensity and more suitable organization.

3.1.2 Farm size and contributions to FSN

It is important to understand what kinds of farms are currently "feeding the world", producing not only calories, but all the components of a diverse and healthy diet (such as macro- and micronutrients, and fibre).

In a previous report, the HLPE stated that "smallholder agriculture is a reality in virtually all countries and regions and that large numbers of smallholders is the norm, not the exception" (HLPE, 2013b). Civil society organizations gathered in Nyéléni (2015) for the International Forum on Agroecology claimed that the small-scale food producers they represent produce together some 70 percent of the food consumed globally. Herrero *et al.* (2017) showed that small and medium farms (below 50 ha) produce globally 51 to 77 percent of nearly all commodities and nutrients examined (including vegetables, sugar crops, roots and tubers, pulses, oil crops, livestock, fruit, fibre and cereals), with key regional differences. In regions such as "North America, South America, and Australia and New Zealand", where large farms dominate, "they contribute between 75% and 100% of all cereal, livestock, and fruit production, and the pattern is similar for other commodity groups. By contrast, small farms (≤20 ha) produce more than 75% of most food commodities in sub-Saharan Africa, South-East Asia, South Asia, and China. In Europe, West Asia and North Africa, and central America, medium-size farms (20-50 ha) also contribute substantially to the production of most food commodities" (Herrero *et al.,* 2017). They also found that the diversity of agricultural and nutrient production diminished as farm size increased, but that, regardless of farm size, areas of the world with higher agricultural diversity produce more nutrients. This analysis provides evidence that both small and large farms are important contributors to food availability, but that very small, small and medium-sized farms produce more food and nutrients in the most populous (and food-insecure) regions of the world than large farms (Graub *et al.,* 2016). Ricciardi *et al*. (2018) combined microdata with agricultural censuses across 55 countries and 154 crop types to estimate that farms below 2 ha in size produced 30–34 percent of food supply from 24 percent of gross agricultural area, using greater crop diversity and having lower post-harvest losses than large farms (above 1 000 ha).

Food production efforts must also be attentive to the needs of smallholder farmers and farmworkers who might be negatively affected by increased large-scale farm production. Intensification processes can worsen vulnerability and FSN for small-scale farmers, by increasing cash crop production at the expense of food crops, degrading water and soil systems, and making it more difficult for smallholders to compete against large-scale production (Rasmussen *et al.,* 2018). In some places, large-scale land acquisition can push out smallholders, violating their fundamental rights and leaving them vulnerable to food insecurity (HLPE, 2011b; Nyantakyi-Frimpong, 2017). Farmworkers' and poorer farmers' FSN status can be worsened when intensification occurs unsustainably, along with the environmental resources on which they depend, such as forests and water supplies (Powell *et al.,* 2015; Rasmussen *et al.,* 2018).

3.1.3 Farm size, social equity and well-being of farm communities

Farm size can have an influence on social equity and community well-being (Lyson *et al.*, 2001; Deller *et al.*, 2003; Crowley and Roscigno, 2004; Foltz and Zueli, 2005; Jackson-Smith and Gillespie, 2005; Donham *et al.,* 2007). The rationale for focusing on and promoting smallholders is that these farming systems can contribute to addressing equity, poverty, FSN, employment and sustainable management of natural resources (HLPE, 2013b; Gollin, 2018; Sourisseau, 2014). Smallholder farmers are also often marginalized politically, with limited democratic voice (Grindle, 2004). Comparisons between communities that differ only in farm size have illustrated important social outcomes (Pretty and Barucha, 2014). The types of socio-economic organization associated with farm size, such as absentee landowners, contract farming, reliance on farm managers rather than owner-operators, are factors that can place communities at risk (Crowley and Roscigno, 2004; Lyson and Welsh, 2005; Jackson-Smith and Gillespie, 2005). Some authors have shown that social connectedness, trust and participation in community life were greater where farm size was smaller (Lobao, 1990; Lyson *et al.,* 2001; Crowley and Roscigno, 2004; Donham *et al.,* 2007).

3.1.4 Farm size and nutrition

Filling the nutrition gap between available foods and foods required for good nutrition needs consideration of nutrition-sensitive food and agriculture systems (Traore *et al.,* 2012). Smallholder farmers and farmworkers make up a high proportion of food-insecure and malnourished people, with 75 percent of the world's poorest households living in rural areas and depending on agriculture (FAO *et al*., 2015; 2017). Numerous studies have found a positive relationship between diversified farming systems and human nutritional outcomes for smallholder farmers (Jones *et al.,* 2014; Powell *et al.,* 2015; Bellon *et al.,* 2016; Demeke *et al.,* 2017). Species richness, one measure of biodiversity, has been found to be highly correlated with micronutrient adequacy in human diets (HLPE, 2017b; Lachat *et al.,* 2018). Wild biodiversity on or near farms also plays an important role in many rural household diets (Powell *et al.,* 2015; HLPE, 2017c). In some cases, market access, remittances, women's control of income, ethnic food preferences or other political, economic and sociocultural factors were greater predictors or mediators of dietary diversity (Lourme-Ruiz *et al.,* 2016; Ng'endo *et al.,* 2016; Nyantakyi-Frimpong, 2017; Sibhatu and Qaim, 2018). Efforts to foster agricultural biodiversity and diet diversity on smallholder farms need to take sociocultural and economic factors into account (Keding *et al.,* 2013; Jones *et al.,* 2014; Ng'endo *et al.,* 2016).

3.1.5 Farm size and innovation

Farm size can impact the way technologies are disseminated and the ability of small farmers to adopt innovative approaches and manage the corresponding risks. Larger farmers might have better access to new technologies and this may put pressure on smaller farmers, who may risk being forced out of farming and becoming landless (Royal Society, 2009). This may be the case when, in some countries, large-size farms also receive abundant support through subsidies and other state programmes (Dorward and Chirwa, 2013; Bruckner, 2016). Processes of technology transfer can serve to exacerbate rather than alleviate poverty and inequalities (Adesina, 2009).

Innovation can allow farms of all sizes to diversify production systems. Integrating crops with livestock illustrates this finding (**Box 13**).

Box 13 Contract grazing models in California[29]

In California and other parts of the United States of America, there is a burgeoning movement of ranchers creating integrated crop and livestock systems (ICLS) through contract grazing models. Ranchers and farmers are exploring how the well-timed movements of animals through cropland can result in enhanced ecosystem function, increased profit, more nutrient-dense food and higher-quality fibre.

For example, in the coastal foothills of California, ranchers are providing contract-grazing services to perennial cropping systems, such as vineyards. Producers use electric fencing to create paddocks within the vineyards and focus the animal impact where needed during the period of time following harvest and before bud-break. The livestock, usually sheep in this example, are moved frequently, at least two to three times a week, depending on the weather and on the needs of the landscape they are grazing. In the vineyards, the sheep act as lawn mowers, weed eaters and pruners, and provide much needed fertility, thus reducing or eliminating the use of herbicides and synthetic fertilizers, and time spent for pruning and mowing, as well as tractor use.

In one large vineyard, savings reached an average of USD173/ha, and reduced fossil fuel consumption. Vineyard managers also report seeing a decline in disease, increased vine vigour and higher-quality grapes. After grazing the vineyards, the sheep are moved to other cropland, for example, orchards, alfalfa hay and wheat stubble, or to public lands to graze down fuel load for fire mitigation. This creates a network of interrelated landscapes, crops and products that are all benefiting from the positive ecosystem services of the same flock of sheep. Scientists at the University of California Davis are currently conducting research to more fully document some of these ecosystem impacts and Fibershed, a California-based non-profit organization, has set up a climate beneficial verification model whereby these producers can access a higher premium for their products from brands that support agricultural systems that drawdown carbon.

3.1.6 Farm size, economic risks and resilience

With respect to resilience and adaptation to climate change, intensification (often involving farm consolidation and transitions to larger farm sizes) may change the balance of economic risks to which producers are exposed (Garnett and Godfray, 2012). The concentration on a single or smaller number of agricultural outputs exposes farmers to shocks of negative prices and inclement weather, which presumably are then compensated in years of good prices and weather. Reliance on a few commodities in the global market can expose a national economy to price shocks, and price volatility

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[29] See: https://www.fibershed.com

can create “international poverty traps” in which the poor are unable to escape poverty (HLPE, 2011a; UNCTAD, 2002, 2013). Large-scale farmers of different sizes have ways of hedging their options in the face of uncertainty. Larger farmers may be able to take out insurance against crop failures and price shocks, while small farmers contend with uncertainty through diversifying their production systems, and often their sources of income.

3.1.7 Farm size as a focus of policy

Farm size remains a critical issue in policy as many countries pursue policies intended to promote smaller or larger farm sizes. Some countries, reasoning that larger farms imply economies of scale and contribute more to economic growth, seek to promote land consolidation and land markets, through land titling. Other countries seek to limit consolidation, through restrictions on land markets and farm sizes (Gollin, 2018). This raises the question: “In what ways should governments address issues of farm size to best secure FSN for their populations?” From the evidence presented here, a greater focus on the small- and medium-sized farms that currently provide the major portion of the world’s nutrition, building on the advantages of their small scale and inherent diversity, might be a sound investment.

In 2013, the HLPE recommended that every country should engage in the elaboration of a National Smallholder Investment Strategy, based on a vision for smallholder agriculture, and the accompanying set of policies and budgets to support the transformation of the smallholder sector (HLPE, 2013b).

Supporting networks of farmers, scientists and civil society groups to promote the sharing and co-creation of knowledge to manage these diverse, complex agroecosystems across and between farm and research communities would be required rather than measures that favour large-scale enterprises (Holt-Gimenez, 2006; Brescia, ed, 2017; Nyantakyi-Frimpong *et al.,* 2017; Khadse *et al.,* 2018; Mier y Terán *et al.*, 2018; Nicholls and Altieri, 2018).

In contrast, a number of large-scale farming operations, working with researchers, are starting to address ways in which they may make transitions to more agroecological practices, through introducing the diversification lost in conventional systems, and thus enhancing both performance and resilience (Helmers *et al.,* 2012; Zhou *et al.*, 2014; Leibman and Schulte, 2015). In France and Switzerland, for example, there have been significant initiatives by small- and large-scale farms to transition to agroecological practices, supported by government policies, non-governmental organizations (NGOs), academics and social movements (Anderson *et al*., 2019; Bellon and Ollivier, 2018; Gonzalez and Chang, 2018; OECD, 2017; Wezel *et al*., 2018b). Overall, the impact of farm size on transitions to SFS for FSN is not exclusively but strongly linked to diversification. Yet, diversification is not an exclusive characteristic of small-size farms, nor are all small farms diversified. This suggests that diversification might be explored across a range of small to large farm sizes through supportive public policies, research and civil society initiatives.

The analysis of the respective and complementary capacities of both small- and large-sized farms to contribute to SFSs leads us to better acknowledge the plurality of transitions for each of those categories and the capacity to design and implement context-specific policies to deal with this diversity and address FSN at the relevant levels (Sourisseau, 2014).

3.2 To what extent can modern biotechnologies contribute to transitions towards sustainable food systems for food security and nutrition?

The potential for modern biotechnologies (Flavell, 2010) to support transitions to sustainable food systems has been discussed (Lindblom *et al*., 2017) with concerns about governance, ecological, social and health impacts raised by critics, including a symbolic and ethical dimension (Jacobsen *et al.*, 2013; Quist *et al.*, 2013; Heinemann *et al*., 2014; Hilbeck *et al*., 2015; Carolan, 2018a, b). While being widely spread in some areas, such technology represents for some the promise of addressing future development challenges, considering technology as a major engine for agriculture transformation, and for others a symbol of resistance to the excess of a profit- and technology-driven development model. The latter has been exacerbated by a public mistrust in genetically-modified organism technology, in part due to the dominance of a few powerful multinational corporations in this industry (Andreasen, 2014). This has resulted in much opposition in quite many domains, and led the HLPE to acknowledge this as a critical and emerging issue for FSN (HLPE, 2017a).

Modern biotechnology is defined in the Cartegena Protocol on Biosafety (Secretariat of the CBD, 2000) as: (i) *in vitro* nucleic acid techniques, including recombinant deoxyribonucleic acid (rDNA) and direct injection of nucleic acid into cells or organelles; or (ii) fusion of cells beyond the taxonomic family, which overcomes natural, physiological reproductive or recombination barriers, and which are not techniques used in traditional breeding and selection. Modern biotechnologies are used to develop products by directly altering the traits or characteristics of organisms.

Sequencing provides information that may be used in bioinformatics for such purposes as associating genes with traits (Heinemann *et al*., 2019). The sequences used as markers for desirable traits can by synthesized to produce molecular probes to screen organisms for the desired sequence variations and use them in breeding or clonal propagation (Lidder and Sonnino, 2011). In addition, DNA sequences can be used to verify ingredients in food that come from conserved, protected or locally prized species.

One kind of product derived from modern biotechnology is called a genetically modified (GM) or genetically engineered (GE) organism (GMO or GEO). The commercially dominant examples of GMOs are herbicide- and/or pest-tolerant crop plants, such as soybean, maize, cotton, canola and sugar beet. These were created by insertion of DNA from other species, sometimes referred to as transgenesis. The herbicide- and/or pest-tolerance then makes it possible to eliminate or reduce the use of chemical pesticides and its consequences for health and the environment. Other examples of GMOs include radiation and chemical mutagenesis and gene/genome editing techniques (Altpeter *et al.,* 2016; Sauer *et al.,* 2016). Site-directed nucleases such as CRISPR-Cas9,[30] transcription activator-like effector nucleases (TALENs)[31] and zinc-finger nucleases (ZFNs) for editing genes enable precision breeding of plants and animals and the engineering of industrial microbes (Pacher and Puchta, 2017; Salsman and Dallaire, 2017; Yin *et al.*, 2017; Donohoue *et al*., 2018).

Metabolic engineering technologies have enabled control of metabolic pathways through manipulation of the transcriptome[32] and epigenome,[33] taking modern biotechnologies beyond just the manipulation of the sequence of nucleotides in DNA molecules. For example, RNAi-mediated silencing[34] is being developed and tested to possibly prevent cold-induced sweetening of potato tubers, enhance processing quality (Hameed *et al*., 2018) and control mycotoxin in crops (Majumdar *et al*., 2017). High-docosapentaenoic acid (DHA) in oilseeds using multi-gene construct design is an example of the addition of a process that has been used for the production of land-based long chain polyunsaturated omega-3 oils (Petrie *et al*., 2014).

3.2.1 Modern biotechnologies, health and nutrition

The significant example of beta-carotene-enriched (“Golden”) rice that might be released in the near future illustrates the potential of GM crops to contribute to addressing malnutrition. Golden rice can deliver biologically relevant concentrations of beta-carotene that when ingested is converted into vitamin A. However, barriers still constrain its widespread use to address malnutrition. First, Golden rice involves an estimated 70 patents and 32 patent-holders, all of whom had to agree to the use of their intellectual property (Spielman, 2007). Such a process is cumbersome, expensive and non-scalable. The patent-holders in this case did agree after years of negotiation to issue a humanitarian licence, allowing free use of the seed in eligible countries. Adopters can violate their licence, and be subject to rent charges, if Golden rice seeds mix with exported rice. As there is a demonstrated gene flow risk for rice, GM strategies for nutrition enhancement could create liabilities for poor farmers (Heinemann, 2007, 2013). Second, there are still significant technical challenges to be overcome to

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[30] Clustered Regularly Interspaced Short Palindromic Repeats/RNA-guided endonuclease associated protein 9.

[31] *Transcription* is the first step of DNA-based gene expression, in which a particular segment of DNA is copied into RNA. *Translation* is the process in which ribosomes in the cytoplasm or in the endoplasmic reticulum synthesize proteins after the process of replication of DNA to RNA in the cell's nucleus. The entire process is called *gene expression*.

[32] The transcriptome of a cell or a population of cells is the set of all ribonucleic acid (RNA) molecules, essential in coding, decoding, regulation and expression of genes.

[33] The epigenome of an organism is the reversible and transmissible state of the expression of its genome (genes).

[34] RNA interference (RNAi) is a biological process in which RNA molecules inhibit gene expression, by neutralizing targeted mRNA molecules. Gene silencing (preventing the expression of a certain gene) can occur either during translation or transcription.

reach beta-carotene levels high enough to effectively change the vitamin A status of people consuming Golden rice (Brooks, 2013; Eisenstein, 2014; Glover and Poole, 2018). In addition, GM Golden rice does not perform that well in some rice agroecosystems (Bollinedi *et al*., 2017). Whether or not people are willing to grow and consume these new varieties of rice remains an open question (Bongoni and Basu, 2016). Further, Golden rice does not fully replace diversified production systems that provide a range of nutritional benefits often with cultural significance, both to producers and local markets (Stone and Glover, 2017; Ickowitz *et al.,* 2019). For all these reasons, Golden rice does not prove to date to substitute for diet diversification while encouraging agroecological farming (Jacobsen *et al.,* 2013, Ickowitz *et al.,* 2019).

Another bottleneck in the use of GMOs and GEOs is the lack of data on possible unintended effects. There are, for example, no systematic studies for characterizing CRISPR–Cas9 specificity in plants (Yin *et al*., 2017). There are conflicting reports and limited research on off-target effects with meganucleases, TALENs and ZFNs (Pacher and Puchta, 2017). There are well-documented problems with off-target edits (Yanfang *et al.,* 2013), and major genetic rearrangements and deletions have been reported (Kosicki *et al*., 2018). Some GMO and GEO techniques may result in products that are exempted from GM regulations (Kershen, 2015), although this has become an active area of consultation within many countries.

3.2.2 Modern biotechnologies, health and safety

GM foods are subject to safety assessments by regulatory authorities in national jurisdictions, most of them being based on the comparative framework called “substantial equivalence”, proposed by the OECD in 1993 and which “embodies the idea that existing organisms used as food or a source of food can be used as a basis for comparison when assessing the safety of human consumption of a food or food component that has been modified or is new” (OECD, 1993). The *Codex Alimentarius* indicates: “The concept of substantial equivalence is a key step in the safety assessment process. However, it is not a safety assessment in itself; rather it represents the starting point which is used to structure the safety assessment of a new food relative to its conventional counterpart. This concept is used to identify similarities and differences between the new food and its conventional counterpart” (FAO and WHO, 2009).

The World Health Organization (WHO) confirmed that existing regulations have ensured that GM foods currently on the market entail no confirmed health hazards but cautioned against overextrapolation. It said that “individual GM foods and their safety should be assessed on a case-by-case basis and that it is not possible to make general statements on the safety of all GM foods. GM foods currently available on the international market have passed safety assessments and are not likely to present risks for human health. In addition, no effects on human heath have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved” (WHO, 2014).

Reflecting on the same issue, the US National Academies of Science, Engineering and Medicine (NASEM, 2016) concluded “that no differences have been found that implicate a higher risk to human health safety from these GE foods than from their non-GE counterparts. The committee states this finding very carefully, acknowledging that any new food – GE or non-GE –may have some subtle favorable or adverse health effects that are not detected even with careful scrutiny and that health effects can develop over time”. However, it issued special precautions about extrapolations to future GM-derived foods from existing GM crops saying that “future GE crops … could greatly expand the use of agricultural biotechnology in the development of biofuels, forestry restoration, and industrial bioprocessing and thus potentially lead to new risk-assessment and risk-management issues” (NASEM, 2016).

The American Medical Association (AMA, 2012) “supports mandatory pre-market systematic safety assessments of bioengineered foods and encourages: (a) development and validation of additional techniques for the detection and/or assessment of unintended effects; (b) continued use of methods to detect substantive changes in nutrient or toxicant levels in bioengineered foods as part of a substantial equivalence evaluation; (c) development and use of alternative transformation technologies to avoid utilization of antibiotic resistance markers that code for clinically relevant antibiotics, where feasible; and (d) that priority should be given to basic research in food allergenicity to support the development of improved methods for identifying potential allergens”.

In other words, these major health authorities all confirmed the need for further safety testing and evaluation of GM foods on a case-by-case basis. Other scientific assessments have noted the lack of scientific consensus on GM safety, and have called for ongoing, rigorous and unbiased testing of biotechnology food and food products (Hilbeck *et al*., 2015; Krimsky, 2015).

3.2.3 Modern biotechnologies, livelihoods and equity

In countries that have adopted modern biotechnologies, beyond conventional breeding and conservation technologies, there is evidence of extreme market concentration in the industries that provide inputs to agriculture, shifts to larger farm economic units and displacement of smallholder farmers, reduced farmer participation in breeding and significant price increases in seeds (Mascarenhas and Busch, 2006; World Bank, 2007b; Glenna and Cahoy, 2009; Heinemann *et al*., 2014; Leguizamón, 2014; IPES-Food, 2017a). The market concentration in germplasm and agrichemicals was accelerated by changes in intellectual property rights' instruments, such as the extension to new biological materials that are effectively derived from modern biotechnology processes (Glenna and Cahoy, 2009; Heinemann *et al*., 2014; Howard, 2015). These socio-economic trends directly affect livelihoods, equity, knowledge and culture. However, there is mixed evidence on whether these trends disadvantage those who continue to farm.

In a four-year study of GM and conventional cotton in the United States of America, Jost et al. (2008) concluded "that profitability was most closely associated with yield and not with technology". In other words, access to the latest germplasm and training can be far more important than the GM trait. High yields combined with high input costs can also reduce farm profitability and/or increase farm debt, weakening resilience, in particular in small-scale farms. This phenomenon, known as the "treadmill effect", has been well documented in modern agricultural systems, which focus primarily on yield (Tietz *et al*., 2013; Carolan, 2016). Farmers' reduced ability to save seeds, combined with fewer options due to increased market concentration, is linked to increased seed costs (Howard, 2015).

Two case studies of Bt cotton in Africa suggest that the livelihood and equity impacts vary considerably according to socio-ecological context (**Box 14**).

Box 14 Livelihood and equity impacts of Bt cotton

Bt cotton in South Africa

Schnurr (2012) evaluates the experiences of smallholder farmers in the Makhathini Flats, South Africa, who have been cultivating Bt cotton since 1998. The high adoption rates achieved soon after its introduction were then used to help convince other African nations to adopt GM crops. However, there is a disconnect between the dominant representation of Makhathini that is celebrated in the scholarly and popular literature and the realities faced by its cotton growers. Yields have not significantly increased, while costs remain high, and the initial high number of Bt cotton growers and area has shrunk to 10 percent of initial adoption rates.

Source: Schnurr (2012).

Bt cotton in Burkina Faso

Bt cotton is no longer grown in Burkina Faso. The cotton sector's integrated credit provisioning scheme provided a mechanism for all socio-economic groups to adopt Bt cotton. High seed prices, however, were likely to dissuade resource-poor farmers from Bt cotton adoption, despite the presence of secure credit institutions. Governance issues, including corruption and late payments, drove large numbers of producers to abandon all forms of cotton production. Bt cotton controlled target pests, but secondary pests emerged, shortening the benefits of the technology. These findings suggest that many issues with Bt cotton adoption in Burkina Faso lie in the social and agroecological context of adoption, which is often not examined in farm-gate analyses of transgenic crop outcomes.

Source: Dowd-Uribe, (2014) and Fok (2016).

The NASEM (2016) found *"little evidence"* that the introduction of GMOs had led to yield gains beyond those seen in conventional crops. In contrast, one meta-analysis of 76 studies on GM maize cropping reported that yields were increased (6–25 percent) and that the GM maize had lower levels of toxins (Pellegrino *et al*., 2018). Klümper and Qaim (2014) found that adoption of GM technology reduced the use of chemical insecticides[35] by 37 percent, increased the yields of crops by 22 percent and increased the profits of farmers by 68 percent. Yet, significant methodological limitations prevent assigning measured benefits to GM traits rather than to other factors. Many of the studies contributing

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[35] That is, not counting the insecticide made because of the GM trait.

to the meta-analysis were based on farmer recall (rather than on actual measurements) of yields, and were only 1–2 years long. Also, the possibility of participant selection and cultivation biases were not assessed (Glover, 2010).

Farmers adopting GMOs are also adopting both the latest germplasm and a management programme designed by the seed seller or researcher. GM seed companies have programmes that finance small-scale, early adopting farmers (Stone, 2011). Other farmers using non-GM varieties often do not have access to the same level of outside support.

The limitations of these meta-analyses could be overcome in the future and resolved with greater certainty as to whether or not there is a net increase in farm-level financial performance attributable to ~GM traits. This would require adoption of standard protocols that can address the multi-factorial sources of yield variation, and the use of representative distributions of studies by crop, country, trait and length of study.

3.2.4 Modern biotechnologies and the environment

To contribute to SFSs, potential short- and long-term impacts of modern biotechnologies on the environment should be identified, assessed and mitigated.

Such impacts may occur in different forms. As an example, the Commission for Environmental Cooperation (CEC, 2004) highlighted the potential of GMOs to contaminate native seeds, including landraces and crop wild relatives, especially in centres of origin and diversity.

Mortensen *et al*. (2012) pointed out the multiple problems of weed resistance, encountered in a relatively short time-span, associated with broad and repeated application of glyphosate associated with the culture of GMO maize on very large areas. Similar weed resistance and negative yield impacts have been widely documented in the United States of America (Heap, 2019). Weed resistance can force farmers to use even more toxic substances or to apply a combination of different herbicides, with possible deleterious effects on human health and the environment.

Bt technology was created to reduce pesticide use, as well as the exposure of non-target organisms to pesticides. Till now, the cultivation of GM crops has produced mixed results regarding pesticide use, with pesticide levels declining on cotton but not substantially on maize; moreover, the widespread use of seed coating of neo-nicotonoids on GM seeds has been shown to significantly impact non-target beneficial soil organisms and pollinators (Hopwood *et al.,* 2016; Pisa *et al.*, 2017). If carefully considered from the beginning as part of a holistic system and not applied as a “silver bullet” technology for one pest, modern biotechnology could be considered, under defined circumstances, as an additional tool for biological pest control practices (Hokkanen and Menzler-Hokkanen, 2017).

3.2.5 Modern biotechnologies and agroecology

Sustainable intensification approaches support modern biotechnology as a possible tool for transitions towards SFSs for FSN (Montpellier Panel, 2013; Kuyper and Struik, 2014). On the contrary, given the way they are implemented and how they are controlled, many authors consider that modern biotechnologies are not compatible with agroecological approaches to SFSs (Holt-Gimenez and Altieri 2013; Levidow, 2015; Vanloqueren and Baret, 2009, Hokkanen and Menzler-Hokkanen 2017). These argue that they are not compatible with several of the key agroecological principles highlighted in Chapter 1, including, for instance, principles 5 (biodiversity), 6 (synergy), 8 (co-creation of knowledge), 9 (social values and diets), 10 (fairness) and, under certain circumstances, principle 2 (input reduction) (Lin, 2011; Holt-Gimenez and Altieri, 2013; Levidow, 2015). Further, the fact that certified organic agriculture does not allow GM crops means that using such technologies would eliminate key income opportunities and value-additions through organic certification.

The increase in monoculture associated with the cultivation of GM crops (Plourde *et al*., 2013) suggests a lack of compatibility with agroecological approaches, and it has been suggested that diversified systems would more effectively address ecological health (Davis *et al.,* 2012; Lechenet *et al*., 2014).

Besides its focus on ecosystem-based agricultural practices, central to agroecological approaches is the issue of how a technology is controlled and by whom. Many critics of biotechnology consider that the use of modern biotechnologies has accelerated power concentration in input markets and, as a consequence, a loss of farmer autonomy, skills and overall agency in the food system (Mascarenhas and Busch, 2006; Vanloqueren and Baret, 2009; Holt-Gimenez and Altieri, 2013; Levidow, 2015; Rock, 2019). The increased power and concentration of a few companies over food systems are in stark opposition to agroecological principles that recognize and support diffuse knowledge sources and people's agency respecting "the knowledge of farmers, indigenous peoples, fisherfolk, pastoralists and forest dwellers" as an integral resource (Pimbert, 2015).

The barriers to adopting the products (but not the tools) of modern biotechnologies for use in agroecological approaches are that the intellectual property rights' frameworks and innovation policies can be in fundamental conflict with democratizing and empowering farmers and their communities (McIntyre *et al.*, 2009; Pimbert, 2015). This is within a context where empowerment is seen as not only critical to foster the innovation needed for FSN, but also for community connections to agriculture that lead to better financial security, education and health.

3.2.6 Prognosis

Despite the uptake of GM technology, debates continue to be polarized and there are public concerns about safety, potential negative environmental impacts, resistance to corporatization of agriculture and concerns about the ethics of gene modification (Bennett *et al.,* 2013). With sustainable intensification, the uncertainties identified for assessing the contributions of modern biotechnologies are addressed through research on a case-by-case basis. Proponents of agroecological approaches, in contrast, generally do not consider modern biotechnology part of a transition to SFSs for FSN because, as presently constituted, there are conflicts with their ecological, democratic governance, sociocultural diversity and other core principles.

There clearly needs to be more investment in agriculture and food research, including in careful assessment of modern biotechnologies, for improving food and nutritional security and delivering sustainable food systems in the wake of climate variability and change (Altpeter *et al*., 2016; NASEM, 2016), and there may be scope for adopting lessons from agroecology going forward. For example, herbicide resistance of weeds has become a major challenge for modern, high-input agriculture. Rather than developing ever more targeted herbicides and crops resistant to these through biotechnologies, an agroecological approach would use cultivation systems that resist weeds, by covering soil, creating intercrops or polycultures that fully occupy the space where weeds might otherwise take hold, and focusing on crop health rather than elimination of weeds (Gbehounou and Barbieri, 2016; Smith and Mortenson, 2017).

On a global scale, the products of modern biotechnologies will be part of the transition towards SFSs for FSN. They are already a significant component of the agricultural systems in a number of countries. There is no conclusive evidence that suggests that they need to be introduced into agroecosystems that currently do not rely on them. Some agrifood systems have not adopted input-intensive models and they may implement transitions to SFSs for FSN that do not require them to incorporate products of modern biotechnologies (Quist *et al*., 2013). In contrast, where high-input models using GM and GE are mainstream, transitions to SFSs for FSN may require re-examining the tools used to foster broad-based innovation rather than focusing on specific technologies. Recent calls for a global observatory for gene editing propose increased scrutiny, dialogue and deliberation on the use of modern biotechnologies (Jasanoff and Hurlbut, 2018).

3.3 To what extent are digital technologies compatible with transitions towards sustainable food systems for food security and nutrition?

Digital technologies have dramatically re-shaped agriculture and food systems. Yet, they are sometimes contested for their potential negative direct and indirect effects, in particular because of inequalities in access, and for the path dependency they may generate. "Digital technology" is a very broad concept used here to cover the following sets of technologies in agriculture and food systems: precision agriculture; "big data"; automation; and alternative web platforms. The first two are more strongly linked to sustainable intensification approaches, while the latter have also emerged in agroecological and related approaches.

3.3.1 Precision agriculture

In precision agriculture, sensors used in farm equipment are combined with software platforms providing farm-level historical data (on crop production, yields, soil, climate) and weather predictions. These platforms are linked to farmers' devices to advise them about crop management: which crops to plant, which varieties, where and when to plant and when to harvest. Progress in sensing technologies (such as satellite remote-sensing and unmanned aerial vehicles) helps provide and share real-time data for real-time decision support (Higgins *et al*., 2017; Carolan, 2017; Adeyemi *et al*., 2018). Such tools have mainly been used to inform crop management (Beloev, 2016) but similar tools can also be used to monitor farm animals, although their application has so far been limited (Barbedo and Koenigkan, 2018).

Precision agriculture allows farmers to optimize their costs by tailoring input applications (fertilizers, pesticides, irrigation water) to the real needs, at the right time, in specific locations (Aubert *et al*., 2012; Adeyemi *et al*., 2017; Lovas *et al*., 2018). Precision agriculture deals with in-field variation in levels of nutrient mineralization; however the magnitude of this variation is quite small relative to the levels of fertilizer input (Cambardella *et al*., 1994). Precision agriculture does not necessarily encourage farmers to eliminate inputs that reduce biodiversity or have other damaging impacts on ecological health, and the focus may instead be on optimizing yields (Carolan, 2017; Gkisakis *et al*., 2017).

Precision agriculture can be used to enhance the efficiency and sustainability of the farming system and to reduce yield gaps (Lindblom *et al.*, 2017; Bucci *et al*., 2018) by facilitating integrated pest and weed management, soil amelioration, and weather and climate forecasting (Robertson *et al*., 2017, 2018). Improvements in yield and water productivity may be obtained by better matching crop genotypes to management practices (Kirkegaard and Hunt, 2010). Improved productivity and farm profits can be obtained when a whole-farm precision agriculture approach is used, which also considers the physiological processes of the crop and the relationship between crop development, environment and yield (Monzon *et al.*, 2018). The combination of information on weather forecasts, pest incidence, soil fertility and crop nutrition with artificial intelligence techniques can provide agroecological options for farmers (Ye *et al.,* 2019) and, coupled with remote sensing techniques, can potentially provide more accurate land-cover information for diversified landscape planning (Fu, 2018).

Increased use of precision agriculture technologies in some regions has been dramatic. In the United States of America, only 17 percent of maize was cultivated with precision agriculture equipment in 1997, compared to 72 percent in 2010 (USDA, 2015). Precision agriculture technologies cover 65 percent of the Netherlands' arable farmland, compared to 15 percent in 2007 (Michalopoulos, 2015, cited in Carolan, 2018b). Globally, the precision agriculture market reached USD 2.3 billion in 2014 (Michalopoulos, 2015).

3.3.2 Big data

Big data and high-performance computing, in conjunction with global positioning satellites (GPS), enable farmers to customize input applications for their farm. Machine learning using data for crop management (yield prediction, disease and weed detection, crop quality, species recognition), livestock management (livestock production and animal welfare), water management (evapotranspiration rate and dew-point prediction), and soil management (soil drying rate, soil conditions, temperature and moisture) provides the basis for improved applications in operational environments (Liakos *et al*., 2018). Decision-support systems for farmers made accessible through advances in the Internet of Things (IoT) as well as in information and communications technology (ICT) enable farmers to use evidence to make more informed decisions in real-time.

In the food retail sector, very large data sets are collected from first-party (e.g. loyalty cards), second-party (shared through data agreement) and third-party (social media platforms that identify characteristics of users such as education, income, ethnicity, political affiliation) sources. A combination of predictive analytics and artificial intelligence can be used to "nudge"[36] consumers towards particular purchase choices (Thaler and Sunstein, 2009). With big data, nudges can be layered from multiple sources to create very powerful tools in food retail. Big data can be used in public-sector efforts to help consumers to make more sustainable and healthy food choices through providing information that allows food retailers, public health officials and other actors involved in food systems to shape "choice architecture", i.e. the ways in which choices are presented to consumers, through social cues, norms, built environment and marketing (Thaler and Sunstein, 2009). In contrast, big data and digital technologies shape the food environment (HLPE, 2017b) and can also be used to influence consumer choices in line with the interest of the most powerful actors in food systems, to foster increased use of industrially produced foods, and to encourage unhealthy habits that drive up

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[36] A nudge is "any aspect of choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler and Sunstein, 2009).

profits of food industry companies, at the expense of traditional and locally-based diets, knowledge and skills (Carolan, 2018a). It remains unclear how effective these techniques are, and consumers may maintain autonomy and freedom of choice despite manipulations of choice architecture either aimed at meeting public-health objectives or private-sector profit (Johnson *et al.,* 2012).

Another emerging opportunity is the use of big data to track supply-chain provenance (Kim and Laskowski, 2018).

3.3.3 Automation and alternative web platforms

Automation is anticipated to have significant impacts on productivity in the future (Manyika *et al*., 2017). Automation in agriculture began with large-scale tractors replacing human labour but is accelerating with the use of robotics, drones, automated harvesters and artificial intelligence, increasing productivity and efficiency (Shepon *et al*., 2018). Drones are already used in crop monitoring, crop spraying and field analysis. Automation could free up people from mundane and time-consuming tasks and allow them to participate in community-oriented diverse food production systems (Shepon *et al*., 2018).

However, automation could also have significant negative impacts on employment, in particular in developing countries where the proportion of the total labour force employed in agriculture is high, for example 44 percent in India as compared to a mean of 1.5 percent across Europe and the United States of America (World Bank, 2018; EC, 2018). Disruptions to the labour force could be precipitous rather than gradual because of significant recent investment in automation technologies (Shepon *et al*., 2018). While some productivity gains will be made, without addressing poverty and other factors that affect FSN, these gains are unlikely to impact many food-insecure and malnourished people, including farmworkers.

Alternative food hubs and digital platforms can be used to encourage regional food systems, connecting local producers to consumers and retail outlets and encouraging a circular economy (Carolan, 2017). Web-based platforms have been developed for example, to link: local agroecological food producers with retailers to try to foster regionally-based sustainable food systems; small-scale organic food entrepreneurs with available kitchen space (Carolan, 2017); to develop food-sharing initiatives (Davies *et al.*, 2017b) or platforms that connect farmers willing to share or sell land and farmers with limited access to land.

The use of digital technologies may also serve as a useful and important entry point to draw young people into agroecology (Hung, 2004).

ICT-platforms are important tools for food-sharing networks, providing organizational infrastructure for civic forms of participation in urban food systems, which also serve to reduce waste and bolster FSN for marginalized groups (**Box 15**).

Box 15 ICT platforms to enhance urban food-sharing and reduce waste

Over 4 000 food-sharing initiatives using ICT platforms have been documented in over 100 cities around the world. These food-sharing initiatives involve businesses, non-profit groups, municipalities and residents, and include community gardens, shared eating and cooking in community kitchens and educational food-sharing tours. These initiatives all work to address FSN while reducing food losses and waste.

In Singapore, for example, there are 45 food-sharing initiatives that increase access to local food. In London, collective cookery classes use surplus food while increasing social interaction. In Berlin, public fridges allow food-rescue networks to increase FSN for marginalized urban residents.

Sources: Davies *et al*. (2017), Marovelli (2018) and Morrow (2018).

3.3.4 The digital divide, concentration of power and access to and control over digital technologies.

Digital agriculture can increase dependency on a few input and retail companies (Carolan, 2017; Gkisakis *et al*., 2017) that may decrease resilience and equity of food systems (Higgins *et al.*, 2016). Precision agriculture and automation focus on productivity and yield increases, in line with sustainable intensification approaches, and these technologies are largely controlled by large input companies (Carolan, 2017).

Some farmers still struggle to adapt digital technologies to suit their current practices (Higgins *et al*., 2017). The predominant model, though, is technology transfer, rather than exchange and experimentation, and digital agriculture has been characterized as valuing big data over place-based long-term observation and knowledge of food producers (Carolan, 2017; Higgins *et al*., 2017). This raises key questions of governance about who controls information and technology and who controls access and rights to information (Carolan, 2017, 2018b; Higgins *et al*., 2017), which relates to differing values about community-oriented vs individualistic approaches to developing sustainable food systems (Gkisakis *et al*., 2017; Carolan, 2018b).

Digital agriculture in this sense may lock food producers and citizens into asymmetrical power relationships with large companies who own the platforms and equipment and control the data (Higgins *et al*., 2017; Carolan 2018a). Food retail is highly concentrated – for example, in the United States of America, Australia, New Zealand, Finland, Norway and Sweden, 60, 99, 99, 91, 91 and 91 percent respectively of the entire food retail sector is captured by only five retail firms (Carolan, 2018c). The retail industry increasingly controls what food choices are offered to people as well as a great deal of information about people and what food purchases they make. This may limit choice in the kinds of foods offered and thereby threaten people's agency to transition towards SFSs (Carolan, 2018a).). Depending on how it is used, digital agriculture may close off possible alternative food options that do not satisfy primary industry goals of productivity and profit (Carolan, 2017). Big data in food retail usually focuses on extrinsic attributes[37] that relate consumption of certain types of food as signaling individual achievement and social status. This emphasis further entrenches a focus on productivity and consumer-orientation towards convenience rather than collective action for social change in food production and consumption patterns as citizens (Carolan, 2018a).

A key issue is that precision agriculture is essentially promoted by and profits large agri-input companies, whereas fundamental shifts towards reducing fertilizer and pesticide use are required to transition towards SFSs (IPES-Food, 2016) – shifts that may not be in the interests of input suppliers. Large agro-input companies sell platforms and equipment with an increasing concentration in the big data industry around precision agriculture (IPES-Food, 2017a). Adopting precision agriculture technologies requires a large initial investment in time and capital from farmers (Van Meensel *et al*., 2012), a primary reason for the lower than expected rate of adoption in Europe (Reichardt *et al*., 2009). The high costs of precision agriculture can make it prohibitive for small-scale and lower-income producers (Higgins *et al*., 2017), widening the divide between large- and small-scale farmers. There is a reduced adoption of digital technologies with increasing farmer age and decreasing farm size because fixed costs of equipment make the profitability of precision agriculture lower on smaller farms (Tamirat *et al*., 2018). The lack of access to computers and to the Internet by many small farmers in low-income countries is a barrier to the adoption of precision agriculture (Piwowar, 2018).

The use of expensive digital equipment may lock farmers into a path dependency reliant on ever-more inputs, often associated with debt. An evaluation of the influence of using precision agriculture on the cost of production of crops, farm profits and resource conservation suggests that precision agriculture can promote ecosystem stewardship and increase profits, although it may increase operating costs in some cases (Schimmelpfennig, 2018).

Digital information systems, using tools such as the cell phone and the Internet, already facilitate farmer-to-farmer exchanges in a number of countries, including low-income countries, as well as the ability to establish shorter food chains and build trust among farmers and consumers (Si and Weiping, 2018). If the digital divide[38] was reduced, these technologies could be used by small and medium farms, enterprises, civil society groups and governments to address social and ecological goals. Traditional and local agroecological practices exemplified by the rice–fish co-cultural systems in China could be more easily shared and applied using digital technologies, thereby enhancing agroecological knowledge and more democratic information systems (Xin and Liangliang, 2018).

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[37] Extrinsic attributes of a food product are those that are related to the product but do not form part of the physical product itself such as: brand, labelling and price; as contrasted with intrinsic or sensory attributes such as: colour, flavor, smell or appearance (Li *et al.,* 2015).

[38] A digital divide is any uneven distribution in the access to, use of, or impact of information and communication technologies (ICT) between any number of distinct groups; these groups may be defined based on social, geographical, or geopolitical criteria (NTIA, 1995).

U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA). (1995). *Falling through the net: A survey of the* have nots *in rural and urban America*. Retrieved from http://www.ntia.doc.gov/ntiahome/fallingthru.html.

3.4 Should synthetic inputs be eliminated or used judiciously to transition to sustainable food systems? – The example of fertilizers

Environmental, economic, health and social concerns about the impact of synthetic inputs (fertilizers, herbicides and pesticides) have been a consistent issue raised with regard to transitions to SFSs, with agroecological approaches focused on reduction and phasing them out, while sustainable intensification approaches emphasize making more efficient use of them (Watts and Williamson, 2015; Baudry *et al.*, 2018; Springmann *et al*., 2018). Although similar questions are raised regarding the use of herbicides and pesticides, yet with specific dimensions in particular with regard to human health, the focus here is on fertilizers as an illustration.

Over the past decades, the increasing use of synthetic fertilizers has contributed to raising staple crop yields on all continents (Everson and Gollin, 2003; Pingali, 2012), significantly increasing agricultural production and income, thus reducing global food insecurity. The widespread use of synthetic fertilizers is a direct result of national subsidies in many countries that support their distribution to farmers. In many parts of the world, national agricultural institutions do this as part of a technological package with hybrid seeds (primarily maize, rice and wheat), along with the promotion of pesticide use to protect crops (Poulton *et al*., 2006; Minot *et al*., 2009).

More recently, it has become evident that the widespread use of synthetic fertilizers entailed very high environmental costs, including air, water and soil pollution. Because of their high solubility, synthetic fertilizers pollute surface and groundwater, including coastal and marine watersheds, and provoke toxic algal blooms and aquatic dead zones (Campbell *et al*., 2017; Kirchmann and Bergström, 2007; Howarth *et al*., 2012; Swaney *et al*., 2012). Other studies have measured increased greenhouse gas emissions from the production, transportation and application of synthetic fertilizers resulting in global environmental pollution (Synder *et al*., 2009). The magnitude of impact on the environment depends on several factors including fertilizer type, form and quality, soil type, rainfall amounts, distribution and intensity, and field position and crop management.

Overall excessive fertilizer application is a major contributor to overstepping “planetary boundaries” (Steffen *et al*., 2015). Sutton *et al*. (2011) estimated that the environmental costs of nitrogen (N) losses in Europe outweigh the entire direct economic benefits of nitrogen application in agriculture alone (Sutton *et al*., 2011). Furthermore, long-term field experiments in Africa and China show how the continued and intensive use of synthetic fertilizers, with no addition of organic amendments, can lead to soil degradation and declining yield trends (Waddington, ed, 2003; Miao and Zhang, 2011; Mtangadura *et al*., 2017).

The use of synthetic fertilizers has also entailed socio-economic costs. Reliance on purchased annual inputs has increased production costs, which has led in many cases to increased farmer debt, and subsequent farm business failures (GSA ERS, 2010; IPES-Food, 2016). Generally, the use of synthetic fertilizers requires high purchasing power, so they may be less accessible to marginalized and disadvantaged farmers. Hence, increased reliance on purchased inputs might increase social inequalities (Hooper *et al*., 2002).

Agroecological approaches, such as organic agriculture, agroforestry and permaculture, rely mainly on natural resources, ecosystem services and ecological processes to enhance soil conditions for plant growth, shifting from through-flow nutrient management to a nutrient recycling model and privileging organic rather than synthetic fertilizers wherever possible (Gliessman, 2007, 2015, Maraux *et al.,* 2014; Migliorini and Wezel, 2017). They seek to reduce or to eliminate the use of synthetic and purchased inputs that are damaging for human health and the environment, and to build circular, diversified agroecosystems, anchored on renewable, locally available natural and biological resources (Wezel *et al*., 2014; Shiming, 2016; Gliessman, 2016, de Boer and van Ittersum, 2018). Within such a perspective, the role of livestock is demonstrated as essential (Mottet *et al*., 2017; de Boer and van Ittersum, 2018), as it is pivotal to close biological end environmental cycles and ensure the renewal of ecosystem fertility through closing nutrient cycles (HLPE, 2016).

Several studies have demonstrated the viability of a range of locally adapted organic management practices, including legumes, compost, manure, agroforestry and traditional practices, and including public initiatives to support farmers to transition to organic sources, in particular in Africa (Snapp *et al*., 1998; Coulibaly *et al.,* 2019). Long-term trials have demonstrated that organic management with legumes can maintain phosphorus as well as nitrogen availability in some cases (Gallaher and Snapp, 2015). In Zimbabwe, the use of improved legume fallows resulted in improved maize growth and rehabilitated soil structure (Chikowo *et al*., 2003). In the United Republic of Tanzania, a combination of rock phosphate and *Tithonia diversifolia* (a shrub used in biomass transfer systems) increased maize grain yields and phosphorus availability (Ikerra *et al*., 2006). This strategy, which used locally available rock phosphate, could be considered an agroecological approach. In Malawi, legume intercrops and rotations with maize have significantly improved maize yields and soil quality under smallholder farming conditions (Snapp *et al.,* 1998, 2010). The use of compost and traditional *zaï* soil and water conservation methods (planting basins) in Burkina Faso increased soil mineralization and overall soil quality (Coulibaly *et al.,* 2019).

Box 16 *Zaï*

Zaï is a special form of cultivation in pits to concentrate water and manure (1 to 3 tonnes/ha) in micro-basins (30 to 40 cm in diameter, 10 to 15 cm deep) dug with a short-handled hoe and staggered every 80 cm, where the seeds (sorghum, millet, etc.) will be sown. The soil removed from the hole is deposited downstream of the holes in order to limit erosion and trap the sand, silt and organic matter transported by the wind in the pits. The soil surface that is not worked around the holes serves as an impluvium and therefore increases the amount of water retained in the pits. The organic matter deposited in each micro-basin before the rainy season attracts termites, which dig galleries to the surface; these biogenic structures lined with faeces rich in minerals allow the infiltration of water and the formation of deep water pockets, protected from rapid evaporation, which are exploited by the roots between two rainfall events. Depending on rainfall, a crop can reach 400 kg to 1 000 kg of cereals and the same amount of straw, even on an initially very poor soil.

Source: Derived from http://www.fao.org/3/i1861f/i1861f05.pdf

Organic fertilizers (such as manure, compost and legumes) can provide a natural source of nutrients, improve soil structure and water retention, enhance soil biological activity and sequester carbon. They can release nutrients more slowly and over a longer period of time than mineral fertilizers. Management practices, such as introducing legumes and other green manure crops in crop rotation, as intercrops or as cover crops, can contribute significantly to nitrogen fixation and phosphorus mobilization (Iverson *et al*., 2014; Droppelmann *et al*., 2017; Mapfumo, 2011; Franke *et al*., 2018; Scrase *et al*., 2019). Several empirical long-term studies tend to show that organic systems, using manure, compost or legumes, experience increased soil nitrogen and carbon accrual and lower nitrogen leaching, although caution must be taken with intensive manure systems and more research is required on the use of manure in organic farming practices (Drinkwater *et al.,* 1998; Snapp *et al*., 1998 Drinkwater and Snapp, 2008; Snapp *et al.* 2010; Miao and Zhang, 2011; Tittonell *et al.* 2007).

Organic fertilizers also have limitations. First, some farmers, particularly smallholders, might have limited options for organic fertilization in regions such as southern Africa, where some soils are inherently infertile and degraded (Mapfumo and Giller, 2001; Sommer *et al*., 2013; Mafongoya *et al*., 2007; ICRISAT, 2009; Mapfumo *et al*., 2013). Phosphorus, a key element in plant nutrition, is naturally low within the soil resource-base of much of sub-Saharan Africa and often has to be imported into the crop production system to enhance productivity. Second, some organic nutrient sources available to smallholder farmers may be of low or variable quality, and thus may not have the desired fertilization effects (Palm *et al*., 2001; Mtambanengwe and Mapfumo, 2006). Third, organic nutrients have to be mineralized before becoming available for the plant. This biological process takes time and it might be difficult with organic fertilizers to ensure that the right nutrient source is applied at the right rate, in the right place and at the right time, known as the 4Rs principle (Johnston and Bruulsema, 2014). Critical nutrients can be immobilized when required by crops, or released at a time when they cannot be taken up, leading to nutrient leaching. Finally, organic matter management usually requires extra work, including for harvest of green manures, preparation of manure and compost, and incorporation.

It is important to invest in research, extension and education on alternative approaches to fertilization that combine mineral and organic fertilizers efficiently, considering in particular the diversity of farming systems under a wide range of soil, water and climate conditions (Oladele and Tekena, 2010; Tittonell *et al.* 2007; Sinclair and Coe, 2019). Innovations are most likely to be successful if they take into account locally available resources and the local socio-ecological context. For instance, in low rainfall regions of west and southern Africa, micro-dosing fertilizer technology increased cereal yields by 30 to 100 percent while reducing fertilizer application 30 percent below the recommended amounts (ICRISAT, 2009; Twomlow *et al.,* 2010). Combinations of judicious amounts of mineral fertilizer with organic nutrient resources in integrated soil fertility management can reduce mineral fertilizer use, enhance soil carbon stocks and improve yields (Mtangadura *et al*., 2017).

Whether or not synthetic fertilizers should be eliminated or used judiciously to transition to SFSs, there is a growing convergence towards the reduction and limitation of their use and the agroecological and other innovative approaches analysed in this report offer promising avenues for doing so.

3.5 To what extent can biofortification be part of a transition strategy towards sustainable food systems for food security and nutrition?

Biofortification is often contrasted with growing and consuming a diverse mix of crops as alternative strategies to address nutritional deficiencies in diets. However, much contestation is taking place as to the best strategy and practices to ensure a balanced diet.

Biofortification involves increasing the density of minerals and vitamins in crops through plant breeding, transgenic methods or agronomic practices (Bouis and Saltzman, 2017). This can be contrasted with post-harvest fortification of foods where additions are made to food products during processing. Conventional plant breeding includes, for example, the development of ”orange-fleshed sweet potato” enriched in beta-carotene, iron-rich beans, rice and pearl millet (Finkelstein *et al.,* 2017; Hotz *et al.,* 2012a, 2012b; Mondal *et al.,* 2016). As stated earlier in this report, Golden rice, also enriched in beta-carotene, is an example of biofortification through transgenic breeding (Bouis and Saltzman, 2017; Finkelstein *et al.,* 2017). Agronomic practices that lead to biofortification can involve optimized fertilizer applications, for example zinc-rich wheat (Cakmak and Kutman, 2018), or by providing the appropriate rhizosphere microbiome for a crop (Goicoechea and Antolin, 2017).

In contrast, diversification of production systems is part of an agroecological approach, which involves increasing agrobiodiversity at farm level with both the number of crop varieties and species grown, and at field level with diversified rotations (Frison *et al*., 2011; Powell *et al.,* 2015).

3.5.1 Biofortification, health and nutrition

There is evidence of nutritional impacts from biofortification using conventional breeding methods and this is often included in community-based education and awareness-raising campaigns (Finkelstein *et al.* 2017; Hotz *et al.* 2012a, 2012b; Ruel *et al.,* 2018). Transgenic biofortification has been less extensively tested so there is more modest evidence of nutritional impact (Bouis and Saltzman, 2017; Finkelstein *et al.,* 2017). Laboratory testing has highlighted the potential nutritional impact of zinc-rich wheat fertilization, but the evidence is limited under field conditions (Cakmak and Kutman 2018). Since biofortification as a nutritional strategy does not promote crop diversification, some critics argue that it may in fact reduce people’s food security in the long run, since food producers lose the direct means to produce a range of healthy food options and instead rely on an increasingly concentrated food system (Bernard and Lux, 2017).

As seen in previous chapters, increasing diversity through agroecological approaches is done using cultivar mixtures, polycultures, intercropping, agroforestry, diversified crop rotations and mixed livestock≠crop systems (Wezel and Silva, 2017) as well as harvesting wild species, as traditionally done by many African and Asian farmers (Smith Dumont *et al*., 2014). Numerous studies have shown a significant, positive relationship between diversified production systems and FSN, either through direct consumption, or income generated through the sale of diversified food products (Bellon *et al.,* 2016; Demeke *et al.,* 2017; Girard *et al.,* 2012; Lachat *et al.,* 2018; Luna-González and Sørensen, 2018 ; Jones *et al.,* 2014; Pandey *et al*., 2016; Powell *et al.,* 2015).

Inclusion of conventionally-bred micronutrient-rich crops that can be reproduced by food producers themselves could be in keeping with an agroecological approach, but as part of agrobiodiverse options. Some agroecological initiatives have used orange-fleshed sweet potatoes, for example, as one of a range of food options for increasing vitamin A in diets.

There is limited understanding of the impacts of biofortification on overweight and obesity (Herforth *et al*., 2015).

3.5.2 Biofortification, livelihoods and equity

One of the premises of biofortification is that increased production of a specific nutrient-rich crop will offer new market opportunities for farmers who grow these crops, and in turn improve their FSN (Rao, 2018). While some conventionally-bred biofortified crops such as orange-fleshed sweet potato have demonstrated positive income benefits for producers, these impacts vary based on market opportunities, seed infrastructure, input costs, socio-economic and institutional factors (Laurie *et al*., 2015; Low *et al*., 2017; Rao, 2018). Transgenic and agronomic biofortification, which rely on capital-intensive technological inputs, are more likely to increase farmers' reliance on purchased inputs (IPES-Food, 2016). Gender and other inequalities operating in a given socio-economic context may lead to differential benefits of biofortified crop production and sales, with the risk of exacerbating inequalities (Stone and Glover, 2016; Rao, 2018).

As seen previously, diversifying production systems may reduce the risks of reliance on a few food products as a source of income (Powell *et al*., 2015) with evidence that diversification is positively correlated with household income for small-scale food producers (Scherr and McNeely, 2007; Pelligrini and Tasciotti, 2014; Córdova *et al*., 2018) although more research is needed in this area, and these impacts would probably also vary based on market availability as well as other socio-economic and institutional factors.

Biofortification is an expert, scientific-driven strategy that may lead to deskilling and marginalization of food producers and consumers (Brooks, 2013; Kimura, 2013; Stone and Glover, 2016). Critics argue that this "charismatic crop" approach focuses on technologically-driven single-food solutions, rather than supporting transitions to SFSs that would include agrobiodiversity as a key characteristic (Brooks, 2013; Kimura, 2013). In contrast, supporting local knowledge about agrobiodiversity and wild species is a key component of agroecological approaches to diversifying production systems (Torres *et al*., 2018; Yang *et al*., 2018). Offering local communities choices with respect to adopting biofortified crops, diversifying their production systems or both, requires information about the alternatives and needs to extend to consumers of food as well as producers.

3.6 Should biodiversity be conserved in agriculture or only in the wild?

There is a long-standing debate about the extent to which conserving biodiversity within agricultural landscapes ("land-sharing"), associated with diversified farming fundamental to agroecological approaches, can contribute to meeting conservation goals, as opposed to maximizing the land area available only for conservation purposes through more intensive agricultural production on the land area devoted to it ("land- sparing"), fundamental to sustainable intensification approaches. The land-sharing versus land-sparing debate has already been raised in the two previous HLPE reports on Sustainable Agriculture for Development in 2016 (HLPE, 2016) and Forestry in 2017 (2017c).

To many concerned with declining biodiversity and the future of nature conservation, agriculture looms as the major global threat and is estimated to be the driver for around 70 percent of the loss of terrestrial biodiversity (CBD, 2014). Multiple studies report precipitous and worrying declines in insect populations around the world, with over 40 percent of insect species now threatened with extinction globally (Sanchez-Bayo and Wyckhuys, 2019). The authors attribute some of these declines to the types of insecticides used in intensive agriculture, with seed coatings that have deleterious impacts on soil and other beneficial organisms. These impacts are not limited to intensive agricultural areas: insect losses of 75 percent recorded a few years ago in Germany occurred in protected areas (Hallmann *et al.,* 2017). Other examples from Europe report ongoing habitat and biodiversity loss in many countries, which to a large extent can be related to agriculture, including pollinators, insects and bird populations (Kluser and Peduzzi, 2007; Pe'er *et al*., 2014; Potts *et al*., 2015; EC, 2017; IPBES, 2018). For birds, the status of 15 percent of bird species is near threatened, declining or depleted and another 17 percent are threatened (European Commission, 2017). Rare birds are not the only ones decreasing, as the decline in common and widespread species is also dramatic (Gross, 2015), and a downward trend for farmland birds is also evident (Pe'er *et al*., 2014). Considering that two-thirds of European endangered or vulnerable bird species live exclusively in agroecosystems (Tucker and Heath, 1994), sustainable agricultural management is of paramount importance to prevent their complete extinction (Pe'er *et al*., 2014; European Commission, 2017).

Critical to this debate is the reality that current agricultural practices in many regions of the world have led to the degradation of an estimated quarter of all agricultural soils, reducing future food production capacity (ISRIC,). Regenerative forms of agriculture that maintain and enhance ecological health and long-term productive capacity of agroecosystems are central to keeping existing farmlands productive and, in this sense, conserving wild ecosystems by reducing the need for further conversion.

In this context, a long-standing debate over the last decade or more has been whether it is best to make agriculture more biodiversity-friendly ("land-sharing") or to sharply separate zones managed for biodiversity from those managed for high-intensity agricultural output ("land-sparing) to meet the aims of both biodiversity conservation and FSN (Green *et al*., 2005).

The central premise of land-sparing is that any alternative form of agriculture other than high-intensity large-scale commercial agriculture will result in lower yields, and thus more land will need to be allocated to agriculture, leaving less land for wildlife and biodiversity in general. Recent studies have shown that particular bird and wildlife species fare better by segregating natural areas from agriculture and other human land uses (Phalan *et al.,* 2011; Hulme *et al.,* 2013; Williams *et al.,* 2017).

From the standpoint of biodiversity conservation, the effectiveness of establishing relatively isolated nature conservation areas, surrounded by a matrix that is inhospitable to biodiversity, has been questioned (Kremen and Merenlender, 2018). Phalan (2018) showed that land savings from the application of Green Revolution farming practices were far less than predicted, in the region of 20 million ha rather than a previously estimated 560 million ha, with higher yields used primarily to produce more, cheaper food, not to spare land for nature. A recent study in Australia investigated the major threats to endangered species, concluding that simply preserving protected land for them will remove threats to only 3 percent of these species, while well-managed protected areas with adequate resources to proactively address threatening processes within their boundary could protect about half of all threatened species. For the other half, however, management beyond their boundaries is needed for their protection (Kearney *et al.,* 2018).

The alternative, as put forth from the "land-sharing" side of the debate, is the creation of landscapes managed so that corridors are created between nature areas and the matrix in between in order to connect areas that are supportive to wildlife, along rivers and through areas of agroforestry, hedgerows or silvopasture (Harvey *et al*., 2006; Kremen and Merenlender, 2018). Thanks to the reduced use of synthetic input, productive lands managed in these ways are able to sustain many ecosystem services, such as pollination, natural pest control and watershed management that in turn sustain crop production.

Many of the most biodiverse areas of the world are also areas of high levels of food insecurity, where simply separating production zones and biodiversity zones required by "land sparing" will not in itself address hunger and malnutrition, and in fact may seriously contribute to disenfranchising local communities and their access to natural resources. The opposing view as proposed by "land sharers" is for integrated landscape management, through different types of production-related enterprises, such as small-scale forestry and fisheries alongside crop production over a "working landscape" (Kremen and Merenlender, 2018). Initiatives explicitly set out to increase the multifunctionality of agricultural landscapes for food production, livelihood improvement and ecosystem conservation have shown positive outcomes, suggesting that trade-offs are not inevitable and multiple objectives in land management are possible (Perfecto *et al*., 2009; Estrada-Carmona *et al.,* 2014).

Management of working landscapes for both production and biodiversity conservation draws on the knowledge and expertise of communities, often stemming from practices and norms that have been shaped over centuries. An emerging trend is community-driven initiatives such as the Satoyama Initiative[39] or the GIAHS[40] that promote collaborations in the conservation and restoration of human-influenced natural landscapes and seascapes, through a deeper global recognition of their value. Respecting these values can serve to empower local communities and sustain cultural traditions, while conserving biodiversity.

Biodiversity conservation efforts have a long history of interacting with governance systems and local communities, and many lessons have emerged. Imposing strict rules to delimit boundaries between natural areas and adjacent communities has often proved to have negative outcomes. Kremen and Merenlender (2018), for instance, evidence a trade-off between the rigidity of restrictions and their enforcement and the likelihood of their effectiveness. Issues of social equity and environmental justice have often not been sufficiently considered (Scoones *et al.,* 2015). Although a broad and diverse range of regulatory, voluntary and market instruments exists to support the concept of integrating biodiversity conservation into productive landscapes, ultimately these hinge on the commitment and

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[39] See: https://satoyama-initiative.org

[40] See: http://www.fao.org/giahs/en/

engagement of communities, including the building of social capital and coalitions among different stakeholders across landscapes and territories (Pagella and Sinclair, 2014). Critical components for building the democratic governance structures needed require community participation in decision-making, social learning and adaptive management (Kremen and Merenlender, 2018). These are all critical elements pointed out by agroecological approaches in aiming for common goals of environmental sustainability and social equity.

As shown in the previous paragraphs and by previous HLPE reports in 2016 and 2017, there is no single universal answer to this debate, which originated from questions raised at the global level to address agriculture-driven deforestation- and environment-related concerns. At the local level, avenues to address such concerns, including mixed arrangements, and their impact may vary according to specific biological, ecological and institutional context.

3.7 Ways to foster innovation for transition towards sustainable food systems

Six controversial issues that reflect contemporary debates have been selected to illustrate the way discussions regarding future avenues for agriculture and food systems are taking place, and the potential contribution from agroecological and other innovative approaches.

Whatever the issue, evidence forces debates to move beyond simple dualistic representation of complex situations. There may be multiple solutions that address concerns and these are usually context and scale specific. In the present context, the recognition of the multiplicity of transition pathways towards sustainable food systems is important. Both incremental transitions at territorial scales and structural changes to institutions and norms at larger scales need to be made. Institutional environments are thus essential to make the transformations needed in food systems happen; this is further developed in Chapter 4.

The generic capacity of principles identified through the analysis of agroecological and other innovative approaches in Chapters 1 and 2 may help in designing appropriate answers and solutions.

Based on a rigorous and inclusive analysis, disagreements have been identified and characterized. Diverging views may prevent stakeholders from engaging in a constructive debate and divert them from elaborating concrete solutions and designing innovative pathways towards SFSs for FSN.

The controversy associated with the six issues discussed in this chapter is often generated by differences in perspectives and convictions, rather than alternative evidence. They are in some cases irreconcilable. However, in most cases, it is possible to identify knowledge gaps around specific metrics of food system performance required to guide innovation. This is why science has a particularly important role to play, to address the knowledge gaps that remain, to provide new evidence that might contribute to resolve conflict and to make critical decisions to foster transitions to SFSs for FSN. The analysis also demonstrates the interest for reformulating controversial issues so that rights based solutions can be designed either to reconcile differences on the one hand, or to make political choices among divergent views on the other.

It is clear from the preceding analysis that fostering innovation towards SFS transitions involves taking measures that can connect individual actors, civil society groups, social movements and institutions in the public and private sector domains, increase dialogue and co-learning and ensure active involvement of producers and consumers in decision-making about food systems (**Figure 7**).

Figure 7 **Coordination between public and private stakeholders for knowledge generation and co-learning to foster innovation towards SFSs**

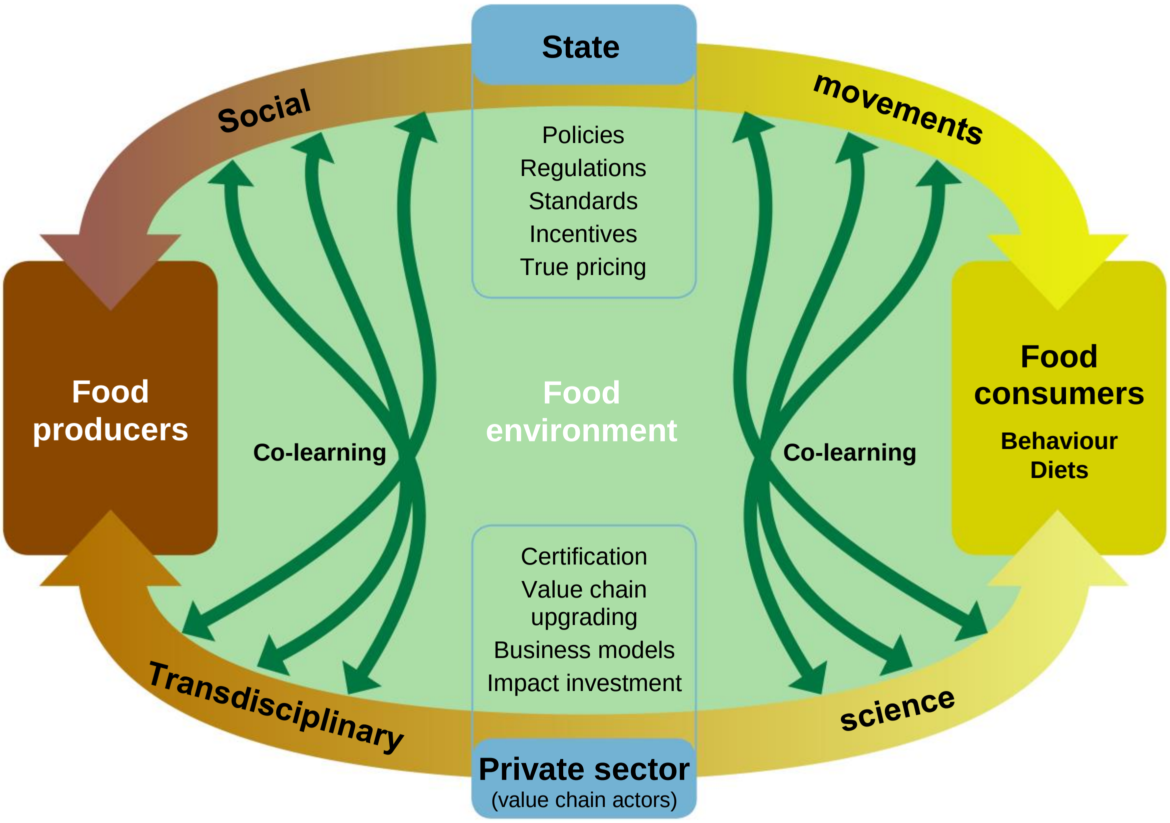

Figure 7 shows how knowledge required to foster innovation towards SFSs for FSN may result from interaction between social movements and problem-focused transdisciplinary science. The first can contribute to the reformulation of what needs to be addressed, to the shaping and dissemination of knowledge and to foster widescale spread of sustainable agricultural practices and other food system innovations through supporting local innovation. The latter contribute to the elaboration of the required knowledge through co-learning. Clearly the richer the interaction between social movements and transdisciplinary science, the more likely it will be that strong co-learning processes can take place, with science embedded in social movements and social movements shaping science.

Figure 7 also reflects how much coordination between public and private stakeholders, including civil society, is pivotal to shape governance that affects innovation towards SFS. The public sector operates through a range of policy instruments, incentives, regulations, standards and attempts to correct market failures, such as moves towards true pricing, whereas the private sector intervenes in value chains through participation in certification, value-chain upgrading, innovative business models and impact investment.

Consequently, as raised earlier in this report, addressing agency within the food system is important, as is addressing ecological footprint from whole food systems. Market forces, left to themselves, will not result in transitions to SFS because there are many externalities associated with production, processing and transit of food from producer to consumer that are not priced (Costanza *et al*., 2017) and because the power exerted from the increasingly concentrated agrifood input and retail sector and related conflicts of interest (HLPE, 2017b) mitigate against addressing these externalities (Howard, 2015; IPES-Food, 2017a).

Individual consumers can, to some extent, exert pressure to close market failures through their purchasing decisions, if there are products produced sustainably, that are affordable, labelled so that consumer choice can be exerted, and if the information about how they have been produced is trusted (Huang *et al*., 2005). Individual consumers, however, have very limited ability to support a widespread transition to SFSs for FSN involving structural changes. Moves within the private sector to upgrade value chains (e.g. Olam International Limited, 2018) and establish and participate in certification schemes, either centrally run or more participatory in their genesis, that guarantee sustainability and social justice along food chains, can contribute to enabling this sort of consumer choice (Mithoefer *et al*., 2018), as demonstrated in the HLPE's report on multi-stakeholder partnerships (HLPE, 2018).

Government policy, regulation and moves towards true pricing hold a promise of implementing the required structural changes, through internalizing all ecological and social effects of production in the price of food, enabling markets to function in ways that would foster transitions towards SFSs (Sukhdev *et al*., 2016). How connections between transdisciplinary science on the one hand, and social movements and CSOs, on the other, contribute to harnessing such a transformation and to developing institutional environments that can trigger and foster transitions towards SFSs for FSN is explored in the next chapter.

4 DESIGN OF INSTITUTIONAL ENVIRONMENTS TO SUPPORT TRANSITIONS TOWARDS SUSTAINABLE FOOD SYSTEMS

The HLPE, through many of its previous publications,[41] has illustrated, from different perspectives, the critical importance of improving FSN for all, as both a necessary condition and a cross-cutting challenge, not only to end hunger and all forms of malnutrition by 2030 (Sustainable Development Goal 2), but also to achieve the whole 2030 Agenda for Sustainable Development (UN, 2015). The HLPE (2017b) called for a radical transformation in our food systems at different scales to address the multiple burdens of malnutrition. There is already enough evidence to act. The short-term costs of action may seem high, but the cost of inaction is likely to be much higher, carrying with it a legacy affecting future generations (HLPE, 2017b).

This transformation is not easy to bring about because a considerable inertia, manifest in policies, corporate structures, education systems, consumer habits and investment in research, favours the currently dominant model of agriculture and food systems improvement in which environmental and social externalities are not fully considered and, therefore, not appropriately factored into decisions influencing the development of food systems meeting expectations for sustainability (Tilman and Clark, 2014).

Overcoming this inertia and challenging the *status quo* implies the need to create a level playing field on which alternative approaches can be equitably assessed and compared. In previous chapters, the HLPE suggested methodological tools that can facilitate this assessment. These comparisons, and the decisions they ground, take place in a global context where food is increasingly moralized (Askegaard *et al*., 2014), on the one hand increasing the prominence of issues around food production and consumption in the policy arena, while on the other making it more difficult to base policy decisions on evidence rather than a judgement among competing convictions (Scott *et al.,* 2016).

Innovation that can contribute to overcoming the prevailing inertia and effectively challenge the *status quo* will require redirection of investments and efforts through support for agroecological and other innovative approaches, able to provide concrete alternatives to the dominant model. These need to embrace the design and implementation of an appropriate institutional and policy environment acrossscales and across sectors (**Figure 8**), that not only removes perverse incentives and lock-ins and addresses conflicts of interest, but goes further to correct market failures and address constraints to investing in sustainable agricultural practices.

Economic viability is a strong driver for adopting new practices (Morel *et al*., 2018). Both public- and private-sector interactions with food value chains, through appropriate governance, including the participation of civil society, constitute the institutional environment within which innovation is either encouraged or discouraged.

Together, the interacting public and private sector governance mechanisms create a series of “sticks” (regulations and taxes) and “carrots” (price premiums, access to credit, resources and insurance) that may shape transitions towards SFSs for FSN (Börner *et al*., 2015). It is useful to view these governance mechanisms and processes as acting across four different levels of integration for which distinct types of agricultural and food system performance measure are relevant (**Figure 8**). These are: individual practices at field level, their integration at farm level that determines livelihood outcomes of producers; integration at landscape level that determines ecosystem service provision; and finally, integration of innovation across whole food systems that determines their ecological footprint and contribution to SDGs.

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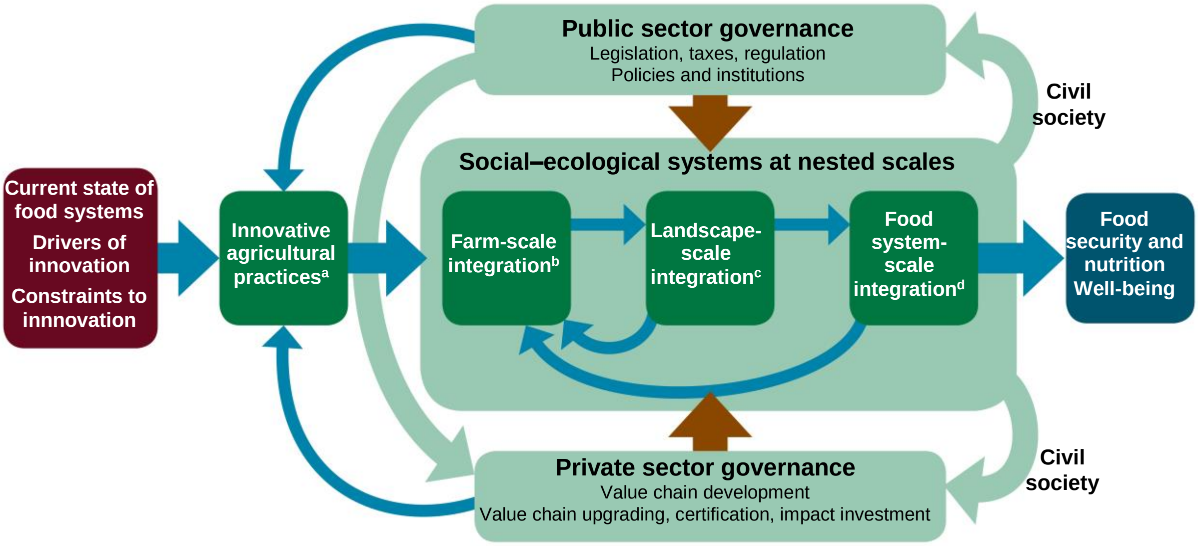
[41] See: http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/CFS-Work/HLPE_contribution_to_CFS_for_SDG-2_2017.pdf, http://www.fao.org/cfs/cfs-hlpe/reports/en/

Figure 8 Influence of public and private sector governance mechanisms on innovation



[a] With performance measures related to their purpose, evaluated across contexts

[b] Total factor productivity and resilience of livelihoods

[c] Provision of multiple ecosystem services – land equivalent ratio multifunctionality

[d] From production through to consumption – ecological footprint

Source: Adapted from Sinclair et al. (2019).

Note: The framework illustrates how public and private sector governance mechanisms and processes influence the institutional environment that shapes innovation across scales of integration. Arrows represent influence with respect to decision making.

In the following sections of this chapter, concrete steps that can help different stakeholders to support transition pathways towards SFSs for enhanced FSN are examined. They are structured into four categories, which were considered complementary to formulate recommendations: (i) performance measures and monitoring frameworks; (ii) support for transitions to diversified and resilient food systems; (iii) knowledge generation and sharing; and (iv) stakeholder engagement and empowerment.

4.1 Performance measures and monitoring frameworks

It is clear that developing and applying appropriate performance metrics and monitoring frameworks for agricultural and food systems is a prerequisite for being able to make rational decisions among alternative innovations intended to support transitions towards SFSs for FSN. Current frameworks essentially focus on yields, volumes and incomes, and do not address the need to value the multi-functionality of the sector (Caron *et al*., 2008) in order to address future challenges. Different performance measures are thus required at different scales (**Figure 8**) and are discussed in the following three sections.

4.1.1 Evaluation of agricultural practices across contexts and their impact on livelihoods

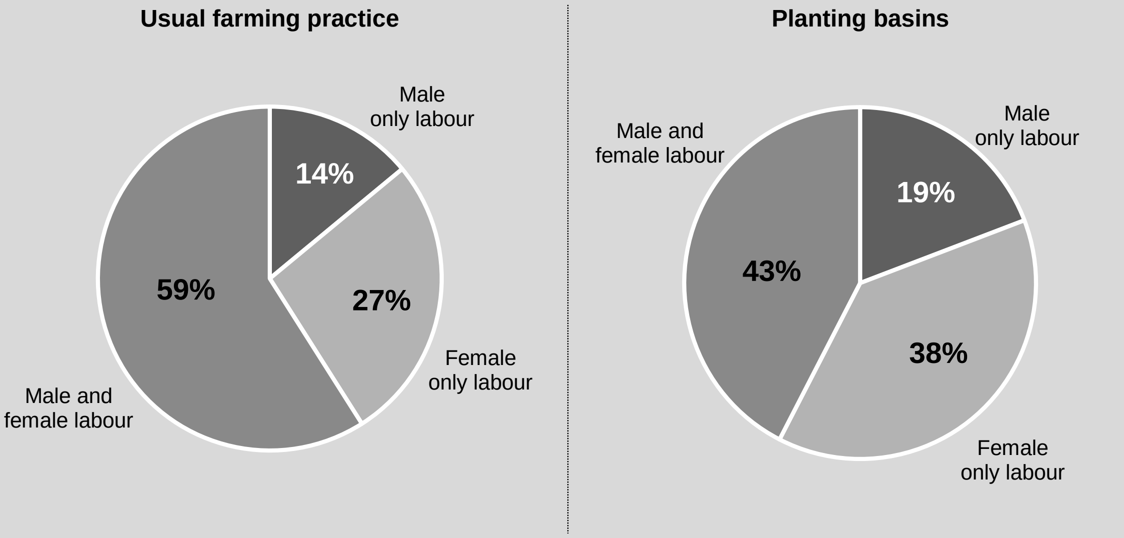
The first two scales of integration in **Figure 8** – that of the field and that of the farm or livelihood – interact strongly because farmers make decisions on adoption of individual practices not only in relation to their field-level performance, but also the implications that adoption will have in the context of their whole livelihood system (Sinclair, 2017). For many smallholder farmers, livelihood systems include non-agricultural components (such as off-farm labour, processing and marketing of products, and remittances) and interactions among a number of household members (Carney, 2002). This means that the performance of agricultural practices needs to be assessed in relation to their impact on the total factor productivity of livelihoods[42] as well as differentially for different household members such as women and children, who may be differentially affected by innovations either in terms of what they contribute, especially labour, and the returns that they receive, especially income over which they have control (**Box 17**).

Box 17 Differential gender impacts of the adoption of planting basins in Kenya

Planting basins are a simple soil and water conservation technique for dryland agriculture, where holes are dug and crops planted within them. These basins reduce surface water runoff and increase water availability for the crop, thus improving plant survival and growth. In Kenya, over 500 farmers have been comparing the performance of these basins to that of their usual cultivation practices (e.g. oxen and plough). Methods from the INGENAES toolkit[43] were used to explore the risks and opportunities that adoption of planting basins present for advancing gender equality, focusing on how men and women control and benefit from them.

Adoption of planting basins altered the division of labour between men and women with respect to land preparation activities. There was a higher incidence of female-only labour used to dig the basins, compared to the typical planting practice using an ox-drawn plough (**Figure 9**). This suggests a shift in labour between men and women presenting both a risk and an opportunity for women's empowerment. For example, women reported that digging basins had limited their ability to perform other tasks, such as collecting firewood and water. On the other hand, the use of planting basins had increased their autonomy to carry out farming activities that previously required male assistance (e.g. ploughing).

Figure 9 Division of labour for planting basins and traditional cultivation practices



Source: Paez Valencia *et al.* (2019).

The key requirement for field level performance assessment of innovative technologies or practices is to understand how this varies across contexts on actual farms, rather than relying on mean treatment effects from controlled experiments (Coe *et al*., 2019a), and how this meets context-specific expectations of both producers and consumers (Côte et al., 2019). Typically, performance of agronomic innovations varies at a fine scale in relation to a complex set of social, economic and ecological contextual factors and expectations across farms, including how farmers change their behaviour in response to opportunities created by the adoption of innovations (Coe *et al*., 2017b). This results in performance evaluation becoming multi-dimensional, both in terms of measuring

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[42] Total factor productivity (TFP) has often been applied at national level as the ratio of aggregate output (e.g. GDP) to aggregate inputs (of labour and capital) with the growth in output not explained by increased input, representing an increase in economic efficiency. Applied to livelihoods, with appropriate measures of aggregate output and input, change in TFP measures whether livelihoods are improving or not across all dimensions (adapted from Sickles and Zelenyuk, 2019).

[43] See: https://www.agrilinks.org/post/technology-assessment-toolkit

multiple performance indicators such as yield (generally and in respect of climate extremes), labour and other input requirements, or residual effects on soil fertility or pollinator populations, across multiple contexts, such as different farm and family sizes, other agricultural practices and cash flow. Methods have been developed to do this efficiently by embedding planned comparisons in scaling up activity of development initiatives, tapping into farmer networks and utilizing citizen science (Sinclair and Coe, 2019).

4.1.2 Landscape-scale integration and the management of trade-offs and synergies among provision of ecosystem services

As outlined in previous chapters of this report, the efficiency of agricultural production has often been assessed on a narrow basis, focused on the yield of major staple crops per unit of land, rather than embracing the broader range of ecosystem services (ES) and social impacts associated with alternative production methods. In this section the importance of a range of ES and of the biodiversity that underpins them is explored, before discussion of expansion of the concept of ”yield gap” to embrace not only yield of staple crops but also the impact of production on the full range of ES, as variously experienced in different locations with different importance accorded to them by society.

Ecosystems perform fundamental life-support functions upon which human civilization depends (MEA, 2005; Kubiszewski *et al*, 2017; HLPE, 2017c). These become ecosystem services when they benefit people through supporting human existence, health and prosperity (Haines-Young and Potschin, 2009). Ecosystem services have been classified as provisioning (e.g. production of food, fibre and clean water), regulating (e.g. control of the flow of pest and disease organisms or pollinators) and cultural (e.g. spiritual and recreational benefits) with supporting ES (e.g. nutrient-cycling), underpinning and sometimes subsumed within the other three categories. Biodiversity is central to the production of ES through the role that living organisms play in energy and material cycles, carbon storage, soil fertility maintenance and nutrient cycling (M EA, 2005; Power, 2010). The potential impacts of biodiversity loss on the functioning of ecosystems are receiving increasing attention (Kubiszewski *et al.,* 2017).

While measurement systems exist for some ecosystem services within traditional market settings, measures for many are still in their infancy, so existing frameworks rarely include full environmental costs resulting in significant ”externalities” that are not factored into performance measures (TEEB, 2010; Kubiszewski *et al*, 2017). Economic valuation of land- and water-use decisions associated with food production produce very different outcomes, dependent upon which ecosystem services are included in the calculations (**Box 18**).

Global estimates of the value of ES reviewed by de Groot *et al*. (2012), including over 320 publications and 1350 value estimates, ranged from means of 490 Intl$[44]/ha/year for open ocean, to 352 915 Intl$/ha/year for coral reefs, with tropical forest at 5 264 Intl$/ha/year and grasslands at 2 871 Intl$/ha/year. This results in an estimated total value of ecosystem services globally of somewhere between 125 and 145 trillion Intl$/year (Costanza *et al.,* 2014) but with a predicted decline of up to 51 trillion Intl$/year due to degradation of ecosystems by 2050, unless there is a significant transition to greater stewardship on the planet, which could lead to a predicted increase by up to 30 trillion Intl$/year (Kubiszewski *et al*., 2017). Putting a monetary value on ES, while useful in guiding policy decisions, does not imply that one ES is substitutable by another, or that they could or should be commoditized and traded in markets. Indeed, most schemes that reward farmers for providing ES involve rewards for adopting and maintaining land-use practices that are associated with maintaining ES provision rather than the actual buying or selling of ES themselves.

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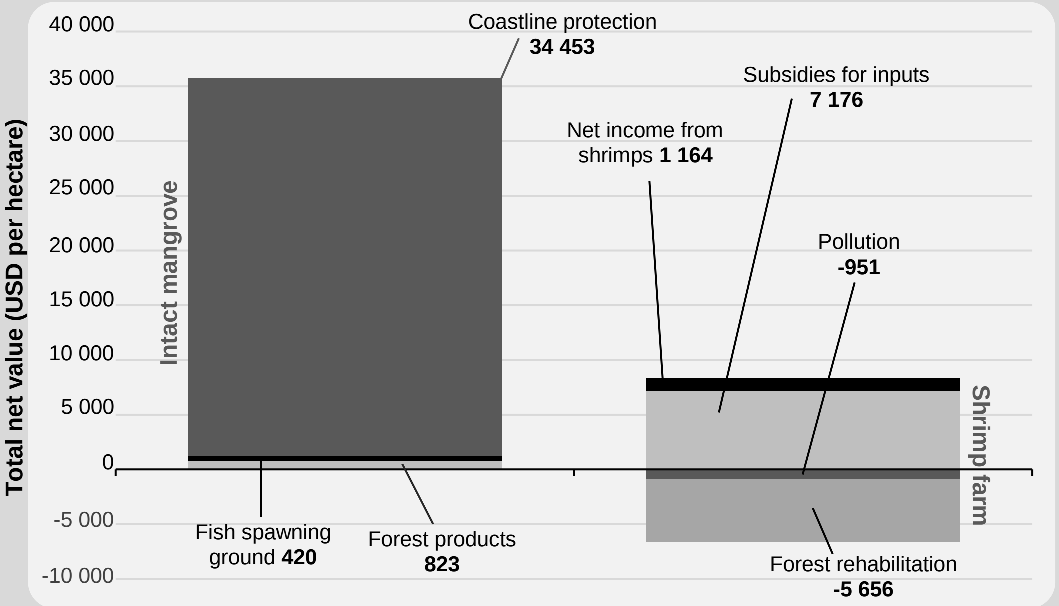
[44] An international dollar (Intl$) is a hypothetical unit of currency that has the same purchasing power parity that the US dollar had in the United States of America at a given point in time, which is 2007 for the figures quoted here.

Box 18 Changing the perspective on the economic viability of converting mangrove to shrimp farming in Thailand

In considering the conversion of mangroves to shrimp farming in Thailand in the 1980s, initial decisions were based on valuing only a single provisioning ecosystem service of aquaculture: the production of shrimps to supply a growing frozen-shrimp export industry. The value of the shrimp harvest was higher than the mangrove's marketable forest products and the profitability of shrimp farming was enhanced by input subsidies. However, when other non-marketed ecosystem services are factored into a broader economic analysis, it can be seen that the conversion of an intact mangrove is not economically beneficial because its value as coastline protection and as a nursery for wild fish is greater than the revenues from shrimp farming. If pollution and costs of restoration associated with shrimp farming are also considered, conversion is even more costly. This illustrates two key issues: first that overall economic viability depends on which ecosystem services are valued; and second that profitability of farming (the economic viability for the farmer) is often not the same as the overall economic value to society because of market interventions.

Figure 10 Comparing mangrove and shrimp profitability: factoring non-marketed ecosystem services



Sources: After Ranganathan et al. (2008) with numbers derived from Sathirathai and Barbier (2007).

Historically, humans have modified natural ecosystems to favour those species that yield direct benefits (e.g. food or wood), generally overlooking other unseen but essential ecosystem services (e.g. pollination, insect control and erosion control) that, if lost, are expensive and sometimes impossible to replace (Power, 2010). Some ecosystem services, such as the regulation and stabilization of climate, water flows (important for flood prevention) or nutrient cycles have not been visible until recent times, when disturbance to them has exacerbated climate change, soil erosion or eutrophication, bringing them to the attention of decision-makers locally, nationally and globally (Mullon *et al.*, 2005). As the loss of ecosystem services becomes a significant cost burden to society, such as in the need to restore degraded river systems, it becomes a priority to understand and value ecosystem services and to integrate them into economic frameworks. Maintenance and restoration of natural ecosystems and the services they provide are, therefore, essential to sustained community well-being, economic prosperity, efficiency and resilience of agroecosystems. The main dimensions of ecosystems are sunlight, soil, nutrients and water, while waste from one part of the system can become a resource for other parts. When ecosystems are modified to meet productivity and profit-oriented goals, they often require additional inputs, such as fertilizers, pesticides or fuel, which can be both beneficial and harmful. The benefits include the production of commodities while the runoff of nutrients or pesticides into streams can result in impaired water quality (TEEB, 2010).

The critical importance of ecosystem services challenges the conventional approach to growth and development, while paving the way for a different approach to prosperity based on a broader conception of well-being (Fioramonti, 2017). Despite progress in a number of areas, ecosystem services will remain marginal in the larger debate until current production and asset boundaries are re-defined to include natural and social capital. Thus, the substantial contribution of ecosystem services to the sustainable well-being of humans needs to be at the core of a fundamental change needed in economic theory and practice if we are to achieve a societal transformation to a sustainable and desirable future (Costanza *et al.*, 2017). Metrics are needed to characterize those elements and so that they can be considered.

Often, rather than embracing a holistic view of ecosystem services, agricultural incentives focus on achieving single outcomes such as fertilizer or pesticide subsidies increasing yield or agri-environmental schemes conserving habitats. They may even conflict, so that managing trade-offs among impacts of land use on ES becomes critical (Jackson *et al.*, 2013). There is a clear need to measure agricultural performance as the sum of its impacts on all the provisioning, regulating and cultural ES and to evaluate trade-offs and synergies among them (van Noordwijk *et al.*, 2018).

Equation 1 The land equivalent ratio multifunctionality metric (LERM) for holistic measurement of agricultural performance at landscape scales

Plot-to-land-scape scale metric for multifunctional land use, perspective **S**

$$\boldsymbol{LERM_s} = \boldsymbol{\gamma_{P,s}} \sum_{\boldsymbol{i}} \frac{\mathbf{P}_{\boldsymbol{i}}}{\mathbf{P}_{i,ref}} + \boldsymbol{\gamma_{R,s}} \sum_{\boldsymbol{j}} \frac{\mathbf{R}_{\boldsymbol{i}}}{\mathbf{R}_{\boldsymbol{j,ref}}} + \boldsymbol{\gamma_{C,s}} \sum_{\boldsymbol{k}} \frac{\mathbf{C}_{\boldsymbol{k}}}{\mathbf{C}_{\boldsymbol{k,ref}}}$$

Societal weighting of provisioning **P** services

Current vs reference services per unit of land

Societal weighting of regulating **R** services

Current vs reference services per unit of land

Societal weighting of cultural **C** services

Current vs reference services per unit of land

Legend:

$LERM_s$ is the plot-to-landscape scale metric for multifunctional land use, perspective **S**
$\gamma_{P,s}$ is the societal weighting of provisioning (**P**) services
P_i is the current provisioning (**P**) services per unit of land
$P_{i,ref}$ is the reference (**ref**) provisioning (**P**) services per unit of land
$\gamma_{R,s}$ is the societal weighting of regulating (**R**) services
R_j is the current regulating (**R**) services per unit of land
$R_{j,ref}$ is the reference (**ref**) regulating (**R**) services per unit of land
$\gamma_{C,s}$ is the societal weighting of cultural (**C**) services
C_k is the current cultural (**C**) services per unit of land
$C_{k,ref}$ is the reference (**ref**) cultural (**C**) services per unit of land

Source: van Noordwijk *et al.*, 2018

The land equivalent ratio multi-functionality metric in **Equation 1** builds on the yield gap concept of expressing what is produced from asn area of land in relation to what that land could produce, i.e. potential production, but considers not just yield but the provision of a range of ES across coherent landscape (or territorial) land units. The measure aggregates all ES appropriate in any particular context, weighted by the importance accorded to them by relevant stakeholders, referred to as societal weighting. This may need to include reconciliation across scales and stakeholder groups whose weighting of different ES may differ.

Operationalizing this sort of metric requires development of social capital (cooperation among farmers and other stakeholders) and policy processes (incentives and regulations) that are implemented at the local landscape scales (10–1 000 km^2) at which many key ES manifest and so can be managed (Pagella and Sinclair, 2014; Crossland *et al.*, 2018). Negotiation tools that support local definition and evaluation of multiple ecosystem services have been developed and used in the formulation of national-level agri-environment policy that embraces appropriate local implementation (Jackson *et al.*, 2013).

4.1.3 Metrics and monitoring frameworks for integrating production and consumption across whole food systems

The global human diet has been identified as a major driver of both human health and environmental sustainability (Willet *et al*., 2019), with what people eat and how their food is produced now recognized as major contributors to widespread environmental degradation (Springmann *et al.,* 2016; Tilman and Clark, 2014). As outlined in Chapter 1 of this report, a central tenet of agroecological approaches to FSN is that they contribute to ecological health rather than degrading the environment through diversified, localized food production that avoids as far as possible the substitution of natural processes by fossil fuel-intensive methods and inputs, including the use of synthetic fertilizers, herbicides and pesticides.

In Chapter 2 of this report, the concept of ecological footprint (Wackernagel and Rees, 1996) was shown to be able to be applied to assess both consumption patterns and the effect of agricultural practices or products on the environment (Bouma, 2010; Lillywhite, 2008). In overall terms, the ecological accounting used to derive ecological footprints relates the area of bioproductive land required for a defined unit of consumption (e.g. that of an individual, a community or a product) to the biocapacity available, indicating that globally aggregated consumption exceeds capacity and is, therefore, environmentally degradative through using up natural capital or ecosystem services (Pulselli *et al.,* 2016).

The utility of the method in developing national and international policy associated with sustainable use of renewable resources has been recognized (Best *et al.,* 2008), although further research and refinement of accounting methods are required to fully capture the concept of biocapacity and trade-offs between different ecosystem services (Wackernagel *et al.*, 2014) as discussed in the previous section.

In Chapter 2 of this report, it was shown that both agroecological and sustainable intensification approaches address the environmental damage that has often been associated with agricultural intensification, through contributing to regenerative processes that restore degraded ecosystem functions (Pretty *et al.,* 2018), particularly by improving long-term soil health (Barrios *et al.*, 2012) to counter widespread land degradation (Lal *et al.*, 2012). A key practical requirement for sustainable agricultural production is the use of practices that are regenerative rather than degradative (Elevitch *et al.,* 2018), but ecological footprint accounting methods at national and global scales at present do not take degradation or restoration into account because the global comparative data required are not collected (Blomqvist *et al.,* 2013; Rees and Wackenagel, 2013).

The utility of including improvement of the ecological footprint as a fourth operating principle underlying transitions towards SFSs was identified in Chapter 2 of this report. A key reason for distinguishing it from resource efficiency – at the heart of the differences between agroecological and sustainable intensification principles – is because it is possible to have high resource-use efficiency at the same time as an unsustainable ecological footprint.

There are other social dimensions of food systems that are important to consider in the development of transition pathways towards SFSs for FSN. A holistic attempt to encapsulate all of these through market mechanisms is the concept of true cost accounting. This is a policy lever gaining increasing attention in food and agriculture (Sukdev *et al.,* 2016). As described above, current patterns of crop and livestock production and processing do not deliver healthy and nutritious food, in large part because their externalities are not included in prices. The implementation of true cost accounting for agriculture and the development of ecological compensation policies could create a “level playing field” and increased equity among different types of agricultural production (Shiming, 2018).

Another important dimension that differs among agroecological and sustainable intensification approaches to food system transitions relates to labour. Some, but not all, agroecological practices can be characterized as being more labour- as opposed to capital-intensive than sustainable intensification alternatives, but are also often promoted as providing opportunities for creating more meaningful employment as discussed in Chapter 2 of this report. This suggests the importance of developing policies that can support the creation of decent, safe and meaningful forms of employment, particularly for young people, but also for marginalized groups such as farmworkers and migrants (ILO, 2017). In many parts of the world, a recurrent problem is the rural exodus of young people in search of better living opportunities in urban areas and the subsequent aging of rural households, hampering innovation and creative solutions to transition to sustainable, thriving communities (FAO, 2014c). What is immediately required is the collection of data on positive and negative employment characteristics in agriculture to underpin development of policies and regulations that favour transitions towards SFSs, including decent conditions for farm labour and strengthening the health of farm- and other food-system workers.

The key dilemma facing policy-makers deciding about appropriate metrics for whole food systems is what to do given the lack of fully comprehensive indicators at this time. In the circumstances, it would seem prudent to adopt indicators, like the ecological footprint, that, while imperfect, at least attempt to connect consumption patterns with methods of production. It is clearly important to acknowledge, while doing this, the need to continue to refine them, and to set up national monitoring frameworks capable of tracking land degradation and restoration in globally consistent ways, that are in keeping with commitments to land degradation neutrality (Aynekulu *et al*., 2017) and that could ultimately incorporate regenerative and degradative land uses into ecological footprint calculations. In the meantime, it will be necessary to supplement the ecological footprint by using a suite of indicators that can capture the social and environmental impacts of food systems that are important individually, rather than relying on a single accounting framework (Blomqvist *et al.,* 2013).

4.2 Support transitions towards diversified and resilient food systems

Significant scientific literature and policy reports have outlined the environmental, social, health and political impacts of the currently predominant agricultural and food system, as well as reasons for its intransigence (Campbell *et al.,* 2017; IPES-Food, 2016; HLPE, 2017b; Vanloequeren and Baret, 2009). Designing enabling conditions and policies in part requires shifting public support towards more diversified farming. Diversified farming systems embrace mixed livestock, fish, cropping and agroforestry that both use and conserve biodiversity and employ vegetation management practices such as intercropping, relay cropping, rotation, cover crops, buffer zones, trap or repelling plants, semi-natural vegetation around farmland and permanent pasture. Diversity needs to be recognized not only in the farming systems themselves but in the transition pathways to get from many different starting points to more sustainable systems, through intensification along different dimensions, suitable for different social, economic and ecological contexts (Côte *et al*., 2019).

The previous chapters outline how small- and medium-sized farms make important contributions in terms of food supply and diverse crops. Unfortunately, imperfect market conditions do not place monetary value on many of their positive social and environmental attributes. Moreover policies are often in support of high-input monocultures (for example input subsidies). Given that many of those households and individuals who experience food insecurity and malnutrition are smallholder farmers, increasing public support for agroecological methods by smallholder farmers would have a double impact, addressing both FSN directly in rural areas as well as transitions to SFSs.

Public support measures that enable small- and medium-sized producers to make greater use of sustainable food production methods could include removing subsidies for degrading practices while giving incentives for sustainable food production methods, or managing multi-functional landscapes including wild species (FAO and INRA, 2018; IPES-Food 2016). It should be noted that a substantial barrier to securing rewards for social and environmental benefits are market failures to not cost the negative externalities of conventional production, nor reward the positive benefits of systems with positive ecological impacts. One of the largest examples of the scaling out of agroecological production is in Cuba, where the state provided significant support for sustainable food production (**Box 19**).

Supporting transitions towards diversified and resilient food systems calls for designing institutional environments for distinct areas of interest, which are developed in the following subsections, in particular territorial management planning, access to genetic resources, promotion of healthy and diversified diets, supporting equitable and sustainable food value chains, and reducing food losses and waste.

Box 19 Case study: Cuba's agroecological transformation

Highlights:

- Over 300 000 farmers use agroecological practices.
- Over half of all vegetables, maize, beans, fruit and pork are produced using agroecological methods.
- The farmer-to-farmer method is a key strategy.
- Land reform, which provided 75 000 new farmers with access to land, helped address SFSs.
- Urban agriculture contributes ~70 percent of vegetables in major cities.
- Agroecological research centres develop locally adapted solutions across the country.
- Agroecology is taught in rural vocational highschools, which includes daily field work.
- Government, university researchers and NGOs have provided technical support to farmers.
- Food security improved; nutritional issues remain a problem for marginalized groups.

Farmers in Cuba have used intensive industrial methods of food production for several decades, with high rates of fertilizer, pesticides and mechanization, but with the soviet collapse in 1989–90, alongside an embargo by the United States of America, they were forced to substitute these inputs. At the same time, the National Association of Small Farmers spearheaded the ”farmer-to-farmer” methodology of teaching and peer-mentoring, which had been learned from farmer organizations in Central America. Starting in 1997, up to 2010, an estimated one-third of smallholder farmers in Cuba received agroecological training using this farmer-to-farmer methodology. While initially smallholder farmers simply substituted organic inputs for synthetic fertilizer (what is termed the ”first stage” of agroecological transition as per Gliessman, 2007), over time they experimented with a range of agroecological approaches, such as intercropping, crop diversification, use of green manures, agroforestry, biological control of pests and integration of livestock with crops. Urban agriculture also increased significantly (Gliessman, 2007), which is important since over 70 percent of the Cuban population live in cities. An estimated 300 000 small-scale farmers use agroecological practices on between 46–72 percent of small-scale farms. Agroecological food production is estimated to contribute 60 percent of vegetables, maize, beans, fruits and pork consumed in Cuba. Urban agriculture, also often using agroecological methods, is estimated to contribute up to 70 percent of fresh vegetables in the larger cities in Cuba. Four key steps have been identified in driving this transition: (i) the farmer-to-farmer horizontal training and systematic knowledge exchange; (ii) farmers treated as the experts in research and exchanges; (iii) development of crop varieties and biological products that are adapted to local conditions; and (iv) building institutional cooperation between stakeholders, including research centres and advisory services for agroecology. The research centres are spread across the country and provide locally-adapted biological pest and disease management solutions, including organic fertilizers, locally-made biopesticides and raising beneficial organisms. Although sustainable food systems have developed considerably and food security has increased, additional initiatives are needed to fully address food security and nutrition. This case study provides evidence of the ways in which farmer-to-farmer agroecology training, combined with scientific networks and cooperation between state, social movements and scientific research, can have significant impacts on SFSs for FSN, but further efforts are needed to address the needs of marginalized groups.

Sources: Mier y Terán *et al*. (2018), IPES-Food (2018), Roset *et al*. (2011), Gliessman (2007).

4.2.1 Territorial management planning

A key element of fostering diversity is territorial management planning across land-use mosaics, including protection of common areas for water, forest and other resources that can be encouraged at a regional level (Caron *et al.*, 2018; **Box 20**). It has already been established in the previous section that the existence of social capital and policy instruments at landscape scales relevant to the resources that need to be managed is important. For biodiversity conservation and ecosystem services such as water regulation (flood control) or pollination, local landscape units (10–1 000 km^2) are a significant scale at which trade-offs and synergies among impacts of land use can be managed, but there are rarely planning tools or processes with a high enough resolution to inform management decisions at this scale (Pagella and Sinclair, 2014).

Since ecosystem service provision at landscape scales is often an emergent property of many land users interacting with market forces, policy levers and societal pressures, influencing outcomes is increasingly seen as a negotiation process. Acknowledging this has led to an evolution from conceiving territorial planning as requiring decision-support tools for a policy-making elite to the development of negotiation-support tools that bring evidence to bear on multiple stakeholder negotiation processes (Jackson *et al*., 2013). Recent developments in geospatial data acquisition and handling make it increasingly possible to marshal real-time evidence about the status of land resources and the impact of policies on them, at the landscape scales that local government seek to influence (Vagen *et al.,* 2018). Data dashboards have been locally designed and used in territorial management planning, as for example in Turkana County, Kenya (Chesterman and Neely, 2015).

Box 20 Example of agroecological territory transition in Brazil

A semi-arid area of northeast Brazil had previously focused on overcoming drought with irrigation and production, with benefits accruing to the political and economic elite. Social movements brought together the ”Northeast Forum”, which presented an alternative programme to the President of Brazil and the provincial governments. They developed a notion of ”*co-existence with semi-aridity*”, which emphasized: (i) conservation and sustainable use of natural and water resources; and (ii) dismantling of monopolies on land, water and other means of production. This new framework encouraged major shifts in management of local resources and social innovations. Examples of social innovations for this transformation of territorial governance to have ”coexistence with semi-aridity” included community seed banks, collective labour, cooperatives, rotating solidarity funds, farmers’ markets and participation in public programmes such as the National School Meal Program and the Program for Family Farms. These innovations were grouped under the category of “partnerships, organization and synergistic relationships between diverse actors”.

Source: Pérez-Marin *et al.* 2017.

4.2.2 Access to genetic resources

The access of farmers to natural resources often claimed by the state, such as land, biodiversity or trees, may be pivotal for ensuring farmer investment in more sustainable forms of production. Barriers to diversification of food systems include intellectual property protection and seed legislation, which might need significant change, depending on the national legal context, to support transitions to diversified production systems. Seed legislation that supports the exchange and access to seeds from genetically heterogenous varieties, including traditional crops, is an important component of this. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), acceded to by 146 countries, includes provision for farmers’ rights and the sustainable use of the genetic resources of 64 crop species representing over 80 percent of global food production. There are, however, perceived tensions between regionally co-ordinated national legislation on plant variety protection (PVP) and the nurturing of farmer-managed seed systems (AFSA, 2017). This comes down to a need to balance the rights of breeders and farmers, in contexts where the former often has a stronger lobbying capacity with governments than the latter.

Many modern varieties have been bred for an industrial agricultural model and may not be optimal for more diversified production systems, so legislation protecting such varieties, especially where combined with input subsidies, can represent a lock-in or path dependency constraining transition to more diversified production systems (IPES-Food, 2016). In some contexts, participatory varietal selection and plant breeding have been successfully combined with nationally regulated seed systems, as in Nepal, where maize varieties selected by farmers for agroforestry contexts and released nationally for use in the mid-hills had a 30 percent higher yield on crop terraces with trees than conventional varieties (Tiwari *et al*., 2009).

In Chapter 3 of this report it was shown that controversy around the use of modern biotechnologies in transitions towards SFSs were focused on how the technologies were controlled and used rather than the fundamental nature of the technologies themselves. This reflects a broader debate in society about the deployment of genetic engineering, intensified by the recent use of CRISPR-Cas9 to correct a mutation in viable human embryos (Jasanoff and Hurlbut, 2018). This has led to a call to set up a global observatory on gene editing along the lines of the Intergovernmental Panel on Climate Change (IPCC), aiming to seek broad societal consensus on the norms that should guide research and the use of technology in this area (**Box 21**). This might contribute to lessening polarization of the debates around the use of modern biotechnologies in pursuit of FSN if the observatory is seen as being sufficiently inclusive to address current power asymmetries surrounding how GE and GM organisms are developed and used.

Box 21 Three proposed functions of a global observatory on gene editing

1. To serve as a clearing-house, consolidating the global range of ethical and policy responses to genome editing and related technologies and making them universally accessible. This would include position statements from civil-society groups, especially from the global south as well as relevant literature. It would report on activities and outputs of formal bioethics bodies, such as the Nuffield Council on Bioethics in the United Kingdom or the German Ethics Council, professional societies such as the American Society for Reproductive Medicine, and intergovernmental agencies, such as the Council of Europe and the World Health Organization.
2. To enable the tracking and analysis of significant conceptual developments, tensions and emerging areas of consensus around gene editing. It would broaden the focus beyond the technical pros and cons of gene editing to a richer range of questions and concerns that tend to be overlooked. Studies of the social dynamics of international collaborations – from setting research agendas to the allocation of intellectual property rights – could help to reveal the hidden power imbalances in science that are likely to influence who benefits from gene-editing research, as well as who does not. Likewise, the material gathered in the global observatory would provide a more detailed view of the biological futures people actually want for themselves and their societies. For instance, it could shed light on differing perceptions of social and biological relationships, such as ideas of disability and disease, across cultures.
3. To serve as a vehicle for convening periodic meetings, and seeding international discussion informed by insights drawn from data collection and analysis.

Source: Jasanoff and Hurlbut (2018).

4.2.3 Promotion of healthy and diversified diets through an appropriate food environment

Diversification of food systems is not only related to production systems but also consumption patterns. Putting greater emphasis on health and nutritional benefits in developing policy has been pursued within nutrition-sensitive agriculture and organic agriculture, as outlined in Chapter 2 of this report and Appendix 1. Bringing in an awareness of nutrition and health has expanded the understanding of how the food environment can be shaped to secure both food security and sustainability benefits. One of the most central of the enabling conditions for improving nutrition is paying attention to gender and social equity issues (see section 4.4). As discussed in Chapter 3 and presented in the HLPE report on nutrition and food systems (2017b), people’s opportunity to choose a healthy, diversified diet depends on the food choices available and how much it costs, the way food is labelled and certified, how much the labelling is trusted and the extent to which private and public institutions seek to nudge consumer choices in particular directions.

The need for public education and awareness raising about SFSs for FSN that use democratic, grassroots approaches is a key enabling condition for transforming food systems. Examples of successful “scaling out” of SFSs, including through agroecology, have often involved public awareness campaigns that worked to change dominant narratives about the food system (FAO and INRA, 2018; Chappell, 2018) and the actions of communities. Public awareness to enable and foster innovations in SFSs should go beyond simple awareness campaigns and engage citizens in ”democratizing innovation” – sharing information and knowledge across networks, addressing social problems and co-producing solutions among communities and researchers (Schot and Steinmueller, 2016). Food sovereignty particularly emphasizes these approaches to public awareness and shared knowledge, including the need to recognize, support and protect local and indigenous knowledge of preserving and cultivating seeds, food and livestock (see section 4.3).

Making use of existing public purchasing obligations can provide economic and political opportunities to implement policy and build new and innovative socio-economic relationships that create SFSs. Public procurement of sustainably produced food, for example, can be provided to low-income and other groups within schools, hospitals and other public institutions, to build mutually reinforcing circuits. The case of *Belo Horizonte* in Brazil is instructive here, as an example of where public procurement of agroecologically-produced food was then used in school meals and in community kitchens that were available to low-income residents, with significant impacts on reducing hunger (Chappell, 2018). Interventions that focus on local procurement of sustainably-produced food for school feeding programmes, or that target groups vulnerable to food insecurity, to realize food sovereignty at local and state level, can be effective in addressing FSN while supporting SFSs (**Box 22**). These initiatives can also support safe, decent, meaningful employment for marginalized groups, including young people and low-income workers within the food system.

Box 22 Feeding cities: addressing urban sustainable food systems

Agroecology and sustainable intensification approaches can be applied to an urban setting. One example of urban agroecology addressing SFSs for FSN is found in Los Angeles, United States of America, which in 2012 established a procurement standard, the Good Food Purchasing Program.[45] Local small and mid-sized farms and food processing operations can receive star ratings based on metrics such as environmentally sustainable farm practices, safe, fairly compensated and healthy working conditions, livestock cared for in a healthy and humane way, and consumers having increased access to quality nutritious food. Since 2012, all city departments and the school district of Los Angeles, which serve 750 000 meals a day, are mandated to use this procurement system. An estimated USD12 million of purchases are now from environmentally sustainable local producers who also meet standards of workplaces, animal welfare and nutrition. At least 150 new jobs were created in food processing, manufacturing and distributing, and 160 truck drivers received higher wages. This procurement system was developed through a collaboration between the Los Angeles Food Policy Council, the Food Chain Workers Alliance and chefs. Several other cities in the United States of America are developing their own Good Food Purchasing Programs. This procurement policy won ”honourable mention” for the Future Policy Award 2018 of the UN World Future Policy Council in partnership with FAO and IFOAM.

In Denmark, the Organic Action Plan (2011–2020)[46] aims to support diversified agroecological farming and secure livelihoods by developing and increasing organic production and markets. A key method of doing so in this policy was to stimulate the demand for organic products by setting a national goal of 60 percent organic in all public kitchens, including schools. A total of EUR6.4 million was earmarked in 2015–2018 for the education of kitchen leaders and workers, and changes in supply chains and menus, to achieve this goal. The city of Copenhagen attained 90 percent organic food in 2015 in public kitchens, without an increase in meal prices.

Sources: Sørensen *et al*. (2015).

4.2.4 Supporting equitable and sustainable food value chains

Supporting equitable and sustainable food value chains is a key enabling condition for development of SFSs for FSN. Supporting the design, control and compliance of quality standards in both long and short supply chains is in particular essential. A particular focus has been developed over the last years on short chains. Farmers who deliver healthy and sustainably-produced food through adequate practices, such as agroecology, need rewarding markets, and consumers need better and reliable access to such products. Supporting short supply chains and alternative retail infrastructures, such as farmers' markets, fairs, food policy councils, and local exchange and trading systems, may enhance farmers' livelihoods and increase access to local, sustainably-produced and diverse food (Hebinck *et al.,* 2015, eds,). Experience shows how much quality control systems adapted to local needs and conditions, and partnerships between public, private and civil society actors, can foster the transition towards SFSs (FAO and INRA, 2018). Policies that support local nested markets that improve livelihoods include:

- enhancing local authorities' (e.g. municipalities) capacity to design local policies that support diversified, sustainable, equitable markets that enhance connections between producers and consumers;
- providing public facilities to host farmers' markets, fairs and festivals for agroecological and other diversified sustainable local producers;
- facilitating the registration of agroecological and other sustainable food producers with trade and food-safety authorities that accommodates their size and production capacity;
- supporting the creation of viable farmer associations that share knowledge and create strong networks to leverage the inputs needed (including alternative inputs, such as cover crop seed);

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[45] See: https://www.futurepolicy.org/healthy-ecosystems/los-angeles-good-food-purchasing-program/

[46] See: https://www.futurepolicy.org/healthy-ecosystems/denmarks-organic-action-plan-working-together-for-more-organics/

- recognizing and supporting participatory guarantee systems (PGS) as a valid means to certify organic, ecological and agroecological producers for more local and domestic markets, which are often more feasible for low-income, small-scale producers;
- developing and strengthening of linkages between urban communities and food production systems, particularly those that support greater food justice and food sovereignty for the urban poor, including consumer cooperatives and multi-stakeholder platforms focused on local and regional markets (**Box 23**).

Box 23 Urban agroecology in Quito, Ecuador: jobs and food for marginalized groups

The Participatory Urban Agriculture Program (AGRUPAR)[47] was established in 2002, after a women-led community consultation process to address the food security needs of vulnerable groups such as the unemployed, refugees, migrants and indigenous people. The Metropolitan District of Quito promotes the production, processing and distribution of food from urban and peri-urban gardens. There are an estimated 4 500 participants annually who produce over 870 000 kg of food on 32 hectares of land, supporting 380 organized groups. This urban agriculture programme annually hosts over 15 organic markets selling these local food products, generates USD350 000 per year of revenue, and has created 100 micro-enterprises and more than 330 jobs with an estimated annual per capita income of USD3 300. The urban gardens promote agrobiodiversity, recycling of organic waste and healthy diets for an estimated 170 000 consumers. The Ministry of Social Development has provided training on urban agriculture, and in 2013 the first collective of urban farmers was formed with 3 000 members. The policy is implemented by the municipal government of Quito, through a collaboration between the municipality, universities, chambers of commerce, the provincial and national governments and business associations. This urban agriculture programme won the Future Policy Silver Award in 2018 of the UN World Future Council in partnership with FAO and IFOAM.

4.2.5 Reducing food losses and waste

A previous HLPE (2014) report has focused on food losses and waste (FLW) in the context of SFS and, because it is such an important element of transition to sustainable food systems, some key aspects are highlighted here, while the reader is referred to the earlier report for substantive detail. There are significant challenges to reducing FLW as it is complex issue. The HLPE report (2014) suggests that there is a need to:

- obtain more accurate data on the amount and location of FLW (Schanes *et al.*, 2018);
- develop strategies that are appropriate for the different levels at which FLW occur;
- ensure that the appropriate steps are taken by various stakeholders with improved coordination.

The reduction of FLW is considered an essential pathway towards SFSs for improved FSN (Cole *et al.,* 2018). FAO estimates that approximately 1.3 billion tonnes of food per annum are wasted. This is one-third of the food produced for human consumption or a quarter of the calories produced that do not enter the human food supply, as they are either lost or wasted (FAO, 2011; HLPE, 2014). Therefore, developing strategies to mitigate food loss from farm to retail, as well as food wasted once it reaches the consumer, is important not only to improve FSN but also to reduce the negative effects on the environment (Lipinski *et al.,* 2013) as well as the energy that has gone into the production of the food (Cuéllar *et al.*, 2010).

As evidenced in the HLPE report (2014), significant FLW occur on-farm, post-harvest, during transport and distribution, packaging, retailing and consumption. FLW quantities along the food chain are different for various commodities and for different regions of the world. A significant amount of food is lost from the human food supply because of safety and quality considerations. For developing countries, food loss usually occurs during production and the post-harvest stage of the supply chain, due to the lack of knowledge and infrastructural support to properly handle food. In developed countries, food wastage usually occurs during post-harvest grading, retailing and at the post-retailing stage (FAO*,* 2011; HLPE, 2014). In addition, some products that do not meet cosmetic specifications but are of acceptable eating quality are rejected due to their appearance (de Hooge *et al.*, 2018;

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[47] See: https://www.futurepolicy.org/global/quito-agrupar/

White *et al.*, 2011). Food is also wasted by consumers who do not understand the “use by” and “best before” dates (Langen *et al.*, 2015). Where there is processing of produce, there can also be food loss due to underutilization of edible by-products and sidestreams of food processing (Augustin *et al.*, 2016).

However, there is insufficient research to minimize FLW in these supply chains, in particular in the Global South (Alamar *et al.,* 2018).

Technologies for post-harvest storage, handling and distribution, processing of food to extend shelf life and for valorization of waste for the creation of new value-added ingredients from FLW are important. A range of preservation and conversion processes, such as freezing, drying, fermentation, canning, pasteurization and sterilization, may be used (Langelaan *et al.*, 2013). Separation processes may be used for the recovery of a range of bioactive compounds as food ingredients or supplements, thus creating a value-added stream for processing waste that would otherwise be wasted (Sagar *et al.*, 2018).

However, strategies to improve consumer understanding will help facilitate the behavioural change required for consumer acceptance of food technologies and processing interventions. Education and embedding community perspectives in policies (Benyam *et al.,* 2018), as well as consumer awareness and standards-setting organizations (Mattsson, 2015), will help people make healthy choices about available sustainable foods. Approaches to reducing FLW have to include all players along the food chain. This requires education and incentives to change individual and collective behaviour and has to be accompanied by institutional incentives (Hertel, 2015).

In various countries, food banks that re-distribute food to vulnerable communities have helped to make them more food-secure. Complementing the experiences analysed in the HLPE report (2014), SAVE FOOD (FAO) provide avenues for global initiatives on FLW reduction (Michelini *et al.,* 2018).[48] Local food clusters (Korhonen *et al.*, 2017) or regional processing hubs to deal with the processing of fresh perishable products into stable ingredients and food products may be options. A future virtual and physical node in the food value chain (FOOD LOSS BANK^{TM}) has been proposed to facilitate the recovery of food loss for processing into ingredients and products (Petkovic, *et al.*, 2017). The digitization of food chains with the use of big data and the Internet of things may provide new practical insights into existing and emergent FLW scenarios and facilitate interventions to reduce food losses (Irani *et al.*, 2018).

4.2.6 Knowledge generation and sharing

A recurring theme throughout this report has been the need to change the relationship between formal research and academic outcomes and the local knowledge and experience of farmers, rural and urban communities and other actors along food value chains, many of whom are in the private sector. Taking steps to achieve greater integration of local and scientific knowledge and of knowledge along food chains requires both investment in strengthening capacity and fundamental reconfiguration of knowledge systems. Addressing knowledge gaps and spanning boundaries between actors, in particular social movements operating with strongly held convictions, represents an essential challenge in a context of increasing concerns about fake information and mistrust in science. This is especially the case when antagonistic positions are held or when doubts about the legitimacy of knowledge from different sources limits capacity to engage in meaningful dialogue and learning.

A key feature of the agroecological approach to innovation is its strong linkages to participatory action research and the promotion of farmer–researcher networks, in which the needs and concerns of the farming community as a whole are taken as the basis for collaborative research (Méndez *et al.,* 2015). It is a central tenet of agroecology that farmers’ knowledge and understanding of management of local natural resources and of local cultural and social systems form the foundation of agroecological approaches. By combining this knowledge with scientific understanding, complex adaptive farming systems can be designed that effectively address transitions towards SFSs (Côte *et al*., 2019). In large part, the role of co-creating knowledge between farmer organizations and researchers has been promoted among farmers and community-based organizations as a distinct pathway towards innovation that is an alternative to the technology transfer paradigm (PKEC, eds, 2017; Pimbert, 2018a). The latter is adapted to the spreading of uniform inventions but not to the tailoring effort required to design context-specific solutions.

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[48] See: http://www.fao.org/save-food/background/en/

Examples of these approaches are found in the Malawi case study (**Box 9**), PROLINNOVA, the McKnight Foundation's Collaborative Crop Research Program, and the Food Security and Sovereignty in the Segovias project in Nicaragua (FAO, forthcoming). These approaches have been applied to climate change adaptation in the United Republic of Tanzania (**Box 24**) as well as farmer–scientist networks in the Philippines (**Box 26**).

Box 24 Agroecological climate-change adaptation in Chololo, United Republic of Tanzania

Located in semi-arid central Tanzania, Chololo is a village of 5 500 inhabitants, reliant on agropastoralism, which has experienced recurrent drought, food insecurity and deforestation. A project was initiated in 2011 by a multidisciplinary team from a government agricultural research institution, a local district authority and three NGOs, with the support of the European Union, to create an "ecovillage" model, drawing on agroecological and participatory approaches. Over 20 different ecological practices in agriculture, livestock, water, energy and forestry were tested and disseminated, using participatory farmer-to-farmer "technology groups". Such practices included the use of rainwater harvesting, water conservation measures, increased use of farmyard manure and optimal planting methods. Women's empowerment was a major focus of project activities. Several livestock practices were also evaluated, including the use of ox-drawn tillage. In addition, several community-wide initiatives were implemented, such as the use of solar-powered boreholes, rainwater harvesting on roofs, reforestation and installation of sand dams. Participatory methods of assessment included community workshops and the use of relevant local indicators. Over a two-year period, households using these ecological practices experienced significant increases in food security, including the number of meals eaten per day, yields and the number of months of household food shortages. There was also an increase in agropastoralists using climate-change innovations, to over half of the village members. Women reported increased decision-making and control over household resources, and a greater involvement in village leadership. There have been subsequent initiatives in neighbouring villages, with increased use of these ecological practices documented. This case study illustrates the potential impact of agroecology and women's empowerment, in addressing SFSs for FSN.

Sources: TOAM (2014) and IPES-Food (2018).

4.2.7 Public and private investment in research

Strengthened *investments* are needed in agricultural and food systems research and development (R&D) (FAO, 2016a). Between 2000 and 2009, global expenditure on agricultural R&D increased by 3.1 percent a year on average (only 2.3 percent a year in low-income countries), from USD25 to USD33.6 billion, almost half of this increase being spent in China and India (FAO, 2017b). FAO estimates that three-quarters of investments in agricultural research and extension are realized in G20 nations (FAO, 2016a). Global R&D investments are focused mainly on major staple crops and other, more nutritious crops such as pulses, fruits and vegetables, as well as the so-called orphan crops, are often neglected (GloPan, 2016; HLPE, 2017b), although positive FSN outcomes can result when they are addressed (see **Box 25**).

Box 25 Using agroecology to preserve orphan food crops – the Bambara groundnut[49]

In most smallholder farming systems, the growing of local landraces has declined significantly primarily due to climate change, dwindling seed supplies and introduction of hybrid varieties. A typical example is that of the Bambara groundnut, a popular grain legume pre-2000 in Mutoko Communal Area in northern Zimbabwe. An initiative of the Agroecological Fund in Mutoko sought to increase the production of Bambara groundnut to promote food security and resilience among farming households in the area. More importantly, the project was designed to create awareness on the importance of conserving traditional food crops and improving nutritional and seed security for the farming communities. Often referred to as a "woman's crop" along with other grain legumes including groundnuts and common bean, the Bambara groundnut is traditionally grown by women farmers on small portions of land, and contains almost 20 percent protein. Seed was procured from the National Genetic Resource Bank for repatriation to farmers. A total of 102 accessions from the genebank and 100 *in situ* conserved seeds from farmers' own retained stocks were planted. Characterization of Bambara was conducted in a participatory manner involving both farmers and researchers, resulting in the documentation of traditional names of the legume and wider acceptance as a cash crop. Farmers were alerted via mobile

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[49] See: http://afsafrica.org/wp-content/uploads/2015/10/Saving-The-Bambara-Nut-in-Zimbabwe.pdf

phones of the producer prices with the highest price of USD80 per 20-litre bucket, and this was a great motivation for them. The cash aspect was an incentive to get the male farmers also participating in the growing of Bambara groundnut. In addition, the repatriation of accessions from the National Genetic Resource Bank to the communities increased the diversity of the farmers' range of Bambara landraces. There was a >90 percent increase in the number of landraces collected for *ex situ* conservation in the National Genetic Resource Bank at the end of the project. Characterization of landraces contributed to the cultural and biodiversity conservation of the underutilized but valuable traditional crop, suggesting an improvement in food and nutrition security at both household and community levels.

Source: Mapfumo *et al.* (2001).

FAO (2014b) highlights the need for sustained investments in *public agricultural R&D* that may generate benefits for the whole society in the long term. However, the *private sector* is also an important actor in agricultural R&D: global private investments in agriculture and food processing R&D increased from USD12.9 to USD18.2 billion between 1994 and 2008 (Beintema *et al.,* 2012). These authors estimate that, in 2008, worldwide total expenditure on agricultural R&D amounted to around USD40 billion in public–private partnerships (PPPs) of which 21 percent was covered by the private sector. Private agricultural research occurs mainly in high-income countries, even if it plays an increasing role in large middle-income countries such as China and India (Beintema *et al.,* 2012; Pardey and Beddow, 2013).

Recent evaluations suggest that public funding of international agricultural research generates very high returns on investment. The economic return from the control of the cassava mealybug in Africa through release of biological control agents alone is sufficient to justify global investment in agricultural research (Nweke, 2009). Analysis of the impacts of its control in Asia illustrates how a good understanding of the system obtained before a ”crisis” hits is essential for a rapid response and thus public investment in ”fundamental” research coupled to a rapid response to urgent emerging issues is needed (Wyckhuys *et al.*, 2018).

The World Bank (2010) considers that public and private sectors play complementary roles in financing innovation, from invention to commercialization,[50] and that appropriate PPPs can be helpful in the intermediary stages of this process. FAO (2014b) argues that: “*the private sector can play a major role in certain types of agricultural R&D, especially in research with less pronounced public goods characteristics; but only publicly funded research is likely to produce the results needed to sustain productivity growth in the long run, especially in many low- and middle-income countries where incentives for private research in agriculture are weaker.”* International, including South–South, cooperation can benefit countries with more limited research and development capacities (FAO, 2014b).

In addition to public and private initiatives, self-organizing, grassroots initiatives for research and innovation led by social movements play an increasingly important role for assessing and promoting agroecological and other innovative approaches. These decentralized forms of people-led research and innovation may sharply contrast with the organization and practice of mainstream agricultural R&D. They work on the basis of an explicit and balanced contract between different categories of knowledge-holders. Examples include the *Campesino a Campesino* networks in Central America and the Caribbean as well as the *Reseau Semences Paysannes* in France (PKEC, eds, 2017; Pimbert, 2018a) and MASIPAG in the Philippines (**Box 26**).

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[50] According to the World Bank, the public sector is responsible for the initial stages, and the private sector can take the lead for the latter stages.

Box 26 Producer–scientist networks – the case of MASIPAG in the Philippines[51]

MASIPAG – Farmer Scientist Partnership for Development (Magssaka at Siyentipiko para sa Pag-unlad ng Agrikultura) from the Philippines is a farmer-led network of people's organizations, NGOs and scientists working towards the sustainable use and management of biodiversity through farmers' control of genetic and biological resources, agricultural production and associated knowledge. The network is spread throughout the whole country, and is composed of more than 500 farmers' organizations – around 35 000 member families. It is estimated that for each member family three other families utilize seeds developed by the network. They also organized more than 180 trial farms, two national back-up farms and eight regional back-up farms. Recently, MASIPAG farmers have been implementing Participatory Guarantee Systems (PGS), locally focused quality assurance systems aimed to certify producers based on active participation of stakeholders and built on a foundation of trust, social networks and knowledge exchange (IFOAM, 2019). A comparative study including data from 840 adopting agroecological practices and non-adopters from across the country (Bachmann et al., 2009) found that:

- 88 percent of farmers found their food security much better after adopting agroecological practices, compared to 44 percent of non-adopters;
- agroecological farmers have increased the diversity of their diets, eat 68 percent more vegetables, 56 percent more fruit, 55 percent more protein-rich staples and 40 percent more meat than previously;
- agroecological farmers on average grow 50 percent more crop types than conventional farmers;
- in the full agroecological group, 85 percent rate their health today better or much better than in the reference year, 2000.

The MASIPAG approach encompasses the following elements:

Bottom-up approach: Decision-making, planning and implementation within the organization come from the membership, coordinated through farmer groups and a decentralized organizational structure.

Farmer-scientist-NGO partnership: Mutual, ongoing learning between farmers, scientists and NGOs.

Farmer-led research: Research, including breeding of new rice varieties, is designed and conducted by farmers.

Farmer-to-farmer mode of diffusion: Training in the network is largely conducted by farmer-trainers using a wide range of techniques including trial farms, exchange days and cultural activities.

Opposition to technological fixes: Holistic change including attention to farmer empowerment and farmer knowledge.

Advancing farmers' rights: MASIPAG works within a broader commitment to farmers' rights. Farmers' rights include rights relating to land, seeds and genetic resources, production, biodiversity, politics and decision-making, culture and knowledge, information and research, and socio-political factors.

There is a need to rebalance the relative contribution of public and private funding of research and development in agriculture and food systems and to clarify the respective roles and responsibilities of public and private actors in the innovation system. Expanding agroecological R&D depends on adequate public funding designed to strengthen decentralized farmer-managed experimentation and learning and grassroots innovation networks. More specifically, public funding is required to support several mutually reinforcing processes for agroecological transformation, including: place-based learning; horizontal peer-to-peer learning for the production of collective knowledge; building extended peer communities to validate and protect collective knowledge; and strengthening local organizations to scale out farmer-managed research and grassroots innovation to more people and places (Pimbert, 2018c).

Supporting the reconfiguration of R&D institutions is desirable so that they are better equipped to address whole food systems and transdisciplinary research along food value chains. Beyond their traditional focus on agricultural production and productivity, agricultural and food R&D institutions should adopt a food-system perspective, and cover all the dimensions of sustainability.

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[51] See: http://masipag.org

Reconfiguring the relationship between scientific research and local knowledge systems can help design innovative transition pathways adapted to each type of agricultural and food system (Côte *et al*., 2019), as the acknowledgement of both the diversity of situations and the need for transformation of all systems lead to an unseen investment in knowledge systems. Participatory R&D methods, involving farmers as well as their local communities and organizations, can help ensure that the results meet their needs and expectations and consider their experience (FAO, 2014b; FAO and INRA, 2016; HLPE, 2016, 2017c).

4.2.8 Knowledge sharing, training and responding to community priorities

Through appropriate education, training and extension systems, governments can improve innovative capacity in the population and facilitate the articulation and implementation of innovative initiatives (OECD and Eurostat, 2005; World Bank, 2010; FAO, 2014b). Improving the access of small food producers (including smallfarmers, pastoralists, fisherfolk and forest-dependent people), in particular women, to extension services is critical to fill the gaps in information, knowledge and technology and may contribute to wider and accelerated transitions towards SFSs for FSN. Producer organizations and communities are expected to play a central role in achieving this (FAO, 2014b).

Continuous learning throughout the lifetime might require new learning models, including vocational training, customized learning, learning-by-doing and teamwork*,* questioning the traditional, vertical learning model of teacher-dominated classrooms with a strong emphasis on rote learning (World Bank, 2010). Community-based learning systems, such as farmer field schools (FFS)[52] or farmer learning centres, where a group of farmers address a problem together in the field, volunteer farmer-trainers and farmer-to-farmer extension services are good examples of such innovative learning models (Mapfumo *et al.,* 2013; FAO, 2014b) . ICT and open access to information and knowledge can also create new ways to generate and disseminate knowledge, building bridges across communities and sectors: mobile phones and specific apps, for instance, have a great potential to improve small food producers access to information, services and markets (FAO, 2014b, 2016b, 2017b).

Diverse farmer and consumer-led initiatives around the world have led to positive changes for SFSs that enhance FSN. One key area of public investment in programmes and interventions that fosters innovations is civil society groups and social movements, which should be strengthened and supported to further encourage a transformation of the agriculture and food system. Support can be provided to marginalized rural farmers' organizations, women's groups, indigenous and community-based organizations, which advocate and train others on the use of agroecological and other innovative approaches for FSN. Public support can be provided in the development of agricultural programmes and training that make use of those ecological processes and functions that sustain agricultural production, shared through participatory involvement of stakeholders, building on local knowledge in the introduction of new practices and collective decision-making. Such training and capacity building may help address the knowledge-intensive nature of agroecology, organic farming and permaculture through providing greater education and information.

Specific measures might include support for: (i) creation of "lighthouses", which are societies or training centres that foster farmer-to-farmer knowledge sharing and create communities of practice (as with the many permaculture centres in different countries and in all continents; (ii) alliances between small-scale producers and civil society groups in urban areas focused on sustainable food systems; and (iii) investment in key aspects of the food value chain in response to community expressed needs, for example the development of small-scale processing plants or storage facilities can be catalytic in changing food systems and enlarging their scope to address FSN.

4.3 Agency and empowerment

The importance of agency – that is, all people being able to exercise choice about what they eat and how it is produced, processed, transported and sold – was identified in Chapter 2 of this report as a fundamental tenet of transitions towards SFSs. Achieving agency implies the need for all people to have access to accurate information and the compliance of the right to food, as well as the ability to secure their rights over the resources required for production, harvesting and preparation of foods (Chappell, 2018). Agroecological approaches stress that a key enabling condition for communities and peoples to

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[52] See: http://www.fao.org/farmer-field-schools/en/

transition to SFSs is through addressing existing power relationships and thereby building their own agency to define and secure their food security within their distinct cultural value systems.

SFSs can be supported by the development of national food policies that set long-term goals at national and regional levels through inclusive processes that embrace grassroots consultation and the involvement of scientists, indigenous groups, farmer cooperatives and other stakeholders. Examples are presented in **Box 28** that point to the potential for agroecology to be used as a policy approach for both large and small farms in Europe to halt biodiversitiy losses. These examples highlight the critical support needed from civil society, governments, business groups, social movements and researchers to address significant barriers (Anderson *et al*., 2018; Wezel *et al*., 2018b) and thus illustrate the importance of considering agency as a key dimension.

A key constraint to formulating and implementing effective policies at the scale of whole food systems is the fragmentation of policy processes among governance bodies. Interministerial mechanisms should be used at the national level to bring together ministries of agriculture, health, gender, environment and education, and include diverse stakeholders, including the rural poor, women, young people and other relevant groups in planning and implementing measures to build SFSs for FSN.

Global institutions that play a key role in the Global South, such as global trade organizations and the international financial institutions, are often perceived as lacking transparency and democratic accountability, particularly for marginalized rural and urban, low-income communities. In this respect, the Committee on World Food Security (CFS) can serve as a model of inclusive civil society involvement and a starting point for improving the power dynamics within global governance systems.

Large-scale land acquisitions that result in loss of access to renewable resources for local populations worsens food security and nutrition for small-scale producers and the rural poor. Support for customary land rights for small-scale producers, and respect for the Voluntary Guidelines on Responsible Governance of Tenure for Land, Fisheries and Forest, adopted by CFS in 2012,[53] would strengthen the ability of small-scale producers, fishers and the rural poor to access land, forests and water sources for ensuring FSN. A good governance structure is a critical element to address access to land, forest, seeds and water (**Box 27**) and to conserve the biodiversity therein (**Box 28**).

Box 27 A successful multi-stakeholder collaboration to develop agroecosystem multi-functions for maintaining eco-agricultural landscapes in China

Longji terraced landscapes in Guangxi Zhuang Autonomous Region, southwest China, designated by FAO as a GIAHS in 2018, are a land-use mosaic comprised of forests, villages, rice terraces and rivers. The forests on the top of the mountains conserve water for rice-growing and domestic water for residents. Terraces produce food and conserve soil and water. Villagers persist in repairing terraces and using clean production patterns for food. They commonly form a circulatory agroecosystem. With urbanization, low economic benefits have challenged its viability. To address this problem, local farmers cooperate with tour companies to develop tourism, taking advantage of the outstanding rice-terraced landscapes and clean farming approaches. They commonly made and agreed on a series of contracts for terraced-landscape conservation and sustainability of tourism development. Local villagers can expect to obtain earnings from not only agriculture, and the services they provide for tourists such as restaurant and hotel operation, but also the tourism income dividend (TID) and the compensation fund for maintaining terraces (CMT) paid by the tourism industry. In 2017, the average total income of households was Yuan Renmimbi 78 131. Of this, agricultural income constitutes just 7 percent of the total local income; the services for tourists account for 71 percent; TID and CMT constitute 19 percent and 4 percent, respectively. Overall, the goal is to develop agroecosystem multi-functionality sustained by local stakeholders who protect terraced landscapes effectively and benefit through improved household income.

Source: Zhang *et al.* (2017)

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[53] See: http://www.fao.org/3/i2801e/i2801e.pdf

Box 28 Public policies and initiatives to transition to transition to sustainable food systems in Europe using agroecology

Biodiversity losses have accelerated in Europe, as evidenced by rapid declines in pollinators, habitat, insects and birds, and has been linked in part to industrial methods of agriculture (IPBES, 2018; Pe'er *et al.,* 2014; Potts *et al.,* 2015). Several policies in different European countries provide examples of how to address biodiversity as a public good through agroecological approaches. In Switzerland, the Government undertook a participatory consultation of its agricultural subsidy programme, which involved farmers' unions, non-profit organizations, environmental and business groups. They also carried out an impact assessment, which took into account economic, environmental and social dimensions of the subsidy programme. As a result, a new Agricultural Policy (2014–2017) was implemented, which increased budgetary payments for the agriculture sector, and provided direct payments to producers who included biodiversity-friendly practices in their farming system. Economic projections suggest that both incomes and productivity will be higher as a result of these reforms (OECD, 2017).

In **France**, a new law to transition to agroecology was initiated by the French Agricultural Minister, which proposed a transformation of agriculture to meet economic, environmental and social performance goals (Bellon and Ollivier, 2018; Gonzalez and Chang, 2018). This initiative included many stakeholders (public service, academia, NGOs, farmers and education institutions) and efforts to reduce pesticides, antibiotics and energy, and to increase organic agriculture. By 2018, EUR10 million had been invested, about 7 500 farms or 9 000 farmers were engaged in agroecological initiatives and organic production had increased, through collaborations called the economic and environmental interest groupings. These are collectives of farmers (with other stakeholder partners) recognized by the government, who engage in a multi-year project of modification or consolidation of their agroecological practices. While there has not been a significant impact to date on biodiversity, there has been an increased mobilization and awareness about agroecology as a viable approach to change agricultural production modes and transform the agrifood system in the French context (Bellon and Ollivier, 2018; Gonzalez and Chang, 2018).

A recent initiative of a consortium of **German** social movements, researchers, NGOS and other civil society actors has proposed a set of policy recommendations to the German Government to also transition to agroecology.

Sources: OECD (2017) and Ministère de l'agriculture et de l'alimentation (2017).

Agency and empowerment are of paramount importance to ensure the contribution from most vulnerable groups in transitions towards SFS, as well as the impact of such transformation for their FSN. This particularly matters for young people and women.

4.3.1 Engage young people in agriculture and food systems

An important dimension of creating an environment that supports transitions to SFSs are policies that can support the creation of decent and safe forms of employment, particularly for young people but also for other marginalized groups of people such as farmworkers and migrants. In many parts of the world, a recurrent problem is the rural exodus of young people in search of better living opportunities in urban areas and the subsequent aging of rural households, hampering innovation and creative solutions to transition to sustainable thriving communities.

The world over, youth participation and involvement in agricultural development may be critical for ensuring sustainable development and FSN (Braun *et al.,* 2000). Lack of immediate benefits and perspectives when they compare to urban promises, poor rural support services, lack of information about appropriate technologies and practices, land degradation and poor infrastructure are some of the factors identified as disincentives for younger people to participate in agriculture (Hung, 2004, Nwaogwugwu and Obele, 2017). Recognizing and addressing the particular constraints and challenges that young people face in trying to establish diversified farming systems and food enterprises (**Box 29**), including access to land, credit and information, are important.

Box 29 Young people involved with agroecological approaches

Youth agriculture and food enterprises in Tigray, Northern Ethiopia

In the Tigray Region, Northern Ethiopia, the Abrha Weatsbha community has been promoting a number of innovative solutions to improve the living conditions of its members. Along with a number of infrastructural developments that improve environmental conditions, such as reforestation of degraded areas, construction of small dams and water catchment ponds, as well as building trenches to restore groundwater functioning, the community has been investing in engaging young people in agricultural enterprises. One of these attempts is to support youth, particularly orphans of military veterans who died during the civil war and the war with Eritrea, to establish their own businesses. The local administration provided them with five hectares to cultivate marketable fruit trees (mangos, avocados, etc.), a recreation centre to host potential tourists and an apiary to produce organic honey. The Institute for Sustainable Development (ISD), a non-governmental organization based in Addis Ababa provided training and capacity building as well as financial and material supplies to assist the youth group in launching their entrepreneurship. In 2012, the Abrha Weatsbha community was awarded the Equator Prize, an initiative within the United Nations Development Programme (UNDP), to recognize outstanding community efforts to reduce poverty through the conservation and sustainable use of biodiversity.

Second generation of youth in agrarian reform settlements in Brazil

The Landless Movement in Brazil (*Movimento dos Sem Terra – MST*) has been promoting a series of initiatives aiming to keep youth in agriculture and to guarantee the rural succession in many of their settlements across the country. Agroecological approaches to manage their area have been playing an important role. One example is agroecological rice production in Rio Grande do Sul, the southernmost state in the country. The MST are the largest producers of agroecological rice in Latin America, involving 616 families in a 5 000-ha planted area (about 5 percent of the total area of rice in the state) in 22 settlements in 16 municipalities. All activities, from land preparation to marketing the rice, are coordinated by an *Agroecological Rice Management Group,* which involves many young people. Another example of creating opportunities for income generation for young people is honey production in MST settlements in Alagoas state, Northeast Brazil. Many young people coming from different state settlements are becoming involved in apiculture and sell the honey in an Agrarian Reform Fair, in Maceió, capital of the state.

Digital and other ICT, embracing all computer-based advanced technologies for communicating and managing information (Cooper, 2000), could be an entry point for youth involvement in agriculture. Younger people have a comparative advantage to engage with the ICT sector that has rapidly grown over the last three decades and has the potential to help tackle emerging challenges associated with agriculture. In many developing countries, significant strides have been made with ICT to relay timely, accurate, reliable and local specific climate information and extension messages (e.g. the Ecofarmer platform in Zimbabwe[54]). Governments, NGOs, social movements and the private sector can take advantage of young people's passion for ICT, and use it as a means to promote agroecology in a world where at least 90 percent of people have access to a mobile phone, with another 40 percent being able to access the Internet (Ayhan *et al.,* 2014).

Information on agroecological practices and related on-time needed information, such as weather forecasts, pest pressure appearances or identification of weeds or pests, with automated image tools or digitalized soil health self-assessment can easily reach today's youth through web-related platforms and ICT tools such as mobile phones, tablets and laptop computers, desktop computers and geographical positioning system (GPS) receivers.

Success stories about agroecological and other innovative approaches can be shared on social media and the short message service (SMS), among many other related platforms, and in this way, spread. ICT can have a multiplier effect among younger farmers provided there is some laid-out goal, which may include economic returns (Nwaogwugwu *et al*., 2017) or simply the joy of watching things grow over time (Hung, 2004). In Kenya, a group of young people recorded significant returns in their agricultural enterprises using SMS and social media to ask questions, discuss issues and interact (Irungu *et al*., 2015), drawing the conclusion that the Internet was the best platform to market and promote agroecology among the young people.

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[54] See: https://www.ecofarmer.co.zw

4.3.2 Empower women and address gender inequality in food systems

There is increasing momentum in the policy arena to address gender inequity, often referred to as gender transformative actions. These are actions that aim to challenge the underlying causes of gender inequality, such as norms, relationships and institutional structures that perpetuate discrimination and imbalances, rather than merely addressing their symptoms (e.g. unequal income, different needs and preferences) to achieve more equitable involvement of women and girls in decision-making, control of resources and control of their own labour and destiny (Hillenbrand *et al*., 2015; Johnson *et al*., 2016). The transformation that is sought is deep, lasting and pervasive, generating change involving a sufficient proportion of the population in a community to surmount a tipping point that ensures change is profound and sustained. While gender is integrated in the previous sections rather than separated out, it is useful to re-iterate here four key dimensions in addressing issues involving gender that are important to formulate recommendations in order to design institutional environments that support transitions towards SFSs, as follows.

1. Recognize women's central roles in agricultural and food systems, to help build the often higher labour demands in holistic agricultural management systems and seeking greater income equity for those providing labour.
2. Develop interventions that provide strategies and tools to deliver nutrition-sensitive agriculture, including next-generation agriculture and food systems on the firm foundation of their knowledge of crop production, food processing and food provision practices, as illustrated in India (**Box 30**).
3. Support farmer-led initiatives that advocate for women's empowerment and address gender inequality, in particular through agroecological and other innovative approaches.
4. Reorient institutions and organizations to explicitly address gender inequalities.

Box 30 Gender-sensitive sustainable value chain approach to minor millets in India

Minor millet species grown in arid regions of Africa and Asia, such as finger millet, little millet, foxtail millet and barnyard millet, are highly drought-tolerant, nutritious, require less water, few inputs and are able to grow under marginal conditions. Poor rural households often produce and consume millets in arid regions, and women play a key role in their production, processing and food preparation. Despite these qualities, minor millets have largely been ignored by governments and research institutions, and total production has fallen in India to about one-quarter of what it was in 1950, in part due to policies that promote maize, wheat and rice at the expense of other crops.

A participatory action research project in four semi-arid regions in India aimed to increase production of these minor millets. The approach involved multiple stakeholders, participatory varietal selection and a holistic approach to the millet value chain, including active involvement of women as producers, processors and consumers of minor millets. A key approach was to address gender inequality at all phases of millet use. Women’s perspectives and involvement were sought out in terms of the additional labour-intensive processing that women undertook with millet, as well as women’s knowledge of key traits for millet in production, processing and cooking methods. In addition, women’s village savings groups, farmers’ groups and women entrepreneurs were key partners in the research process.

Appropriate locally-adapted varieties were identified and tested using participatory varietal selection (PVS) methods and conservation of these varieties increased through seed fairs and developing links with stakeholder platforms. Yield gains for these new varieties ranged from 4 to 74 percent depending on the crop. Fifteen community genebanks were established to help conserve and promote millet diversity.

Production methods of minor millets were improved through participatory research with smallholders to test a range of strategies, including intercropping with pigeonpea, use of vermicompost, linerow planting and use of mechanized weeders. Participatory on-farm testing of these production methods showed yield increases from 39 to 173 percent. Cost–benefit analysis showed a significant increase in income from the combined use of intercrops and improved organic production of millets compared to traditional farming practices – USD254/ha compared to USD137/ha.

As part of a holistic approach, there was also a focus on processing and consumption. Reducing the drudgery of millet processing through the use of several tools such as de-hullers and pulverizers was tested by women’s associations, farmers’ groups and other community organizations. Some of these tools reduced processing from several hours a day to less than 10 minutes.

Fifteen Village Millet Resource Centres were established to provide processing units for millets to reduce women’s workload in processing and increase consumption. Women reported improved self-esteem, social status and reduced workload from these innovations in millet processing.

The development of novel food recipes and promotion of diverse food uses of minor millets was carried out by restaurants, food businesses, women’s cooperatives, schools and hospitals. Several value-added products were developed such as malts and flours, and then marketed by women’s associations. Millet-based recipes were included in several school-feeding programmes. Millet-based recipes were also promoted in workplaces, canteens and hospitals. One study found that students fed with finger millet based-recipes had increased growth and improved iron status, and reported better physical fitness compared to a control group.

Source: Padulosi *et al.* (2015).

CONCLUSION

It is now widely recognized that a major transformation of food systems is needed to achieve food security and nutrition (FSN) globally, and that this will profoundly affect what people eat as well as how it is produced, processed, transported and sold. Transitions to sustainable food systems (SFSs) that reconcile human and ecosystem health with social welfare will not happen without major shifts in policies at international, national and local levels and the active encouragement of innovation across these scales.

There is enough evidence that agroecological approaches are able to contribute to transforming food systems, in particular to deliver agriculture that is regenerative in its use of renewable resources and ecosystem services. We need to act now to remove barriers to transitions based on agroecological principles and address lock-ins that make such transitions difficult to achieve.

In line with previous HLPE reports, the present report clearly demonstrates that specific and distinct transition pathways towards SFSs should be implemented for different types of agriculture and food system, adapted to their contexts and to local expectations. Because of such a diversity and because of the uncertainty and risks related to ongoing and future changes, transitions will be knowledge-intensive. For each of these transition pathways, technology plays an essential role, as part of the innovation process.

In supporting transitions, it is important to recognize that there are areas of convergence and divergence amongst approaches, in particular between agroecological and other sustainable intensification approaches. The characterization of the nature of different approaches and the form of transitions they lead to, set out in this report, will help in selecting approaches appropriate to different contexts and to foreseen transition pathways.

The development of agroecological approaches has increasingly embraced social equity and political dimensions as well as whole food systems, connecting consumption and production. This echoes the need for both incremental transitions and more structural changes to occur in a coordinated and integrated way. Addressing all these dimensions is clearly necessary to foster field- and farm-level transitions, as well as overall sustainability of food systems. However, to date, agroecological approaches have received far less private and public investment in their development than other alternatives and this needs to be re-balanced for the contributions that they can make to be properly appreciated and acted upon.

The development and use of comprehensive metrics of the performance of agricultural and food systems that take full account of all economic, social and ecological impacts are of paramount importance. Different metrics are relevant and appropriate at different scales. For whole food systems, a refined form of ecological footprint, that connects consumption patterns with production methods, should be developed and used.

An analysis of some areas of controversy in this report suggests that divergent views may be driven by polemics, making the design of appropriate pathways difficult. Understanding the reasons for these divergences may ease transitions beyond lock-ins and the formulation of the decisions to be made. This can be illustrated by controversies around the use of modern biotechnologies and digital agriculture, that often revolve more around how they are controlled and used, than the fundamental nature of the technologies themselves. This points to the need to address power asymmetries in innovation across food systems and in how knowledge is generated and disseminated. A reconfiguration of knowledge systems is urgently needed, shifting towards a co-learning paradigm, bringing research and extension closer together and better linking international and national research and extension systems with local knowledge and farmer-to-farmer knowledge exchange.

Environmental and societal drivers have led to an increasing moralization of debates around food, creating, on the one hand, an imperative for policy-makers to act, and making it more difficult on the other hand for policy to move beyond opposed competing convictions. This calls for a strengthening of knowledge systems and a better use of their learning outcomes in policy-making, beyond the mere acknowledgement of the necessity to change. The short-term costs of creating a level playing field for implementing the principles suggested by agroecology may seem high, but the cost of inaction is likely to be much higher.

In line with the CFS commitment to addressing FSN, analyzing the importance of agroecological and innovative approaches shows how the realization of the right to food requires a greater focus on the emerging concept of “agency” as a means of achieving more inclusive progress towards transitions to FSN. The CFS can serve as a model of inclusive civil-society and private-sector involvement and a starting point for implementing transitions towards FSN. Strategies and planning for implementing agroecological and other innovative approaches at different scales (local, territorial, national, regional and global) can help achieve this fundamental transformation of food systems by: setting long-term goals, ensuring policy coherence across sectors (agriculture, trade, health, gender, education, energy and environment), and involving all relevant actors through consultative multi-stakeholder processes.

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APPENDICES

A1 Innovative approaches to sustainable food systems for food security and nutrition

This appendix presents brief descriptions of each of the selected approaches mentioned in Chapter 2. It is intended as a basis for understanding their unique strengths and salient characteristics that might serve as exemplars to other approaches. Both in literature and practice, a wide variety of approaches claim to address various aspects of food security and nutrition (FSN) (HLPE, 2016), with a great deal of overlap. No one initiative addresses all aspects of potential transitions to sustainable food systems (SFSs) for FSN and they are not presented here to suggest a competition of “brands”. Rather it is believed that a dialogue among them can foster cross-learning to help each single approach become more robust and comprehensive. In this sense, we are not providing a hierarchical typology or classification.

Approaches can be very heterogeneous, addressing different aspects of the food chain, and incorporating diverse perspectives on how best to achieve SFS for FSN. In order to classify them, first a list of widely promoted approaches to innovation aiming to enhance FSN was compiled. This list was then iteratively refined by combining sufficiently similar approaches together (such as sustainable intensification, which encompasses conservation agriculture) and splitting those in which distinctions emerged.

A category of rights-based approaches was included, since starting from a rights-based perspective obviously yields outcomes quite distinct from those emerging from other approaches (Wittman, 2011).

On the other hand, given the critical cross-cutting importance of reducing food waste and loss, the dimensions of initiatives around this issue are profiled in Chapter 4 and therefore not in the scope of the present appendix.

A. Rights-based approaches, encompassing food sovereignty, women’s empowerment and right to food

Several approaches to addressing FSN can be subsumed under the term *rights-based approaches*. These address political, social, economic and cultural rights, including food sovereignty, the right to food, food justice and women’s empowerment, which have been considered pivotal areas in the achievement of SFSs for FSN.

Food sovereignty

Food sovereignty, a term that was first launched in 1996 at the United Nations World Food Summit by social movements led by small-scale producers who make up La Via Campesina[55] (LVC), is a broad concept focused on people’s right to control who, how and what kind of food is produced. Key elements of food sovereignty as a framework include: more equitable trade relationships; land reform; protection of intellectual and indigenous land rights; agroecological production practices; and gender equity (Wittman, 2011). The concept of food sovereignty seeks to ensure that trade and market arrangements are transparent, democratic and equitable (Windfuhr and Jonsén, 2005; Fairbairn, 2012). The notion of food sovereignty also emphasizes participation of people in defining agrarian policies, and recognizes the fundamental role of peasant women in agricultural production and all aspects of food (Burity *et al.,* 2010). Food sovereignty has many overlapping themes and approaches with that of the right to food, by connecting food as a human right with the right to choose how and by whom that food is produced (Wittman, 2011). Food sovereignty innovations are most likely ones to originate from a grassroots process, often through the advocacy of social movements, with explicit beneficiaries being local populations.

Principles of food sovereignty: The seven initial set of principles of food sovereignty included: (i) food as a basic human right; (ii) the need for agrarian reform; (iii) protection of natural resources; (iv) reorganization of food trade to support local food production; (v) reduction of multinational

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[55] La Via Campesina is an international movement that coordinates peasants’ organizations from small and medium scale, agricultural workers, rural women, and indigenous and black communities from Asia, Africa, America and Europe. One of the main policies of La Via Campesina is the defence of food sovereignty.

concentration of power; (vi) fostering of peace; and, (vii) increasing democratic control of the food system (La Via Campesina, 1996).

Women's empowerment

Gender inequality is common in many instances, in that men have greater control of resources, sexual rights, positions of authority and domination of political processes, and many cultures attribute a sense of superiority to men (Lorber, 2005). Women's empowerment is an approach to address such inequality. It is a multi-dimensional concept, encompassing social, economic, psychological and political aspects, which includes women's status, agency and autonomy (Pratley, 2016). A common definition proposed by Kabeer (1999) is:

"the process by which those who have been denied the ability to make strategic life choices acquire such an ability."

The term *intersectionality* is relevant to understanding women's empowerment, as it refers to the multiple, overlapping and interactive ways in which race, sexuality, class, gender and other categories of difference can be used as multiple forms of inequality at individual, social and institutional levels (Davis, 2008).

Measurement of gender equity and the related concept of women's empowerment is complex and multi-dimensional (Kabeer, 1999). There is no universally accepted measure, given the variation in gender dynamics, the multi-dimensional nature of gender relationships and sociocultural contexts around the world (Hawken and Munck, 2013; Ibrahim and Alkire, 2007). Nonetheless, numerous measures have been developed to assess gender equity and women's empowerment (Hawken and Munck, 2013). The United Nations Development Programme (UNDP) developed the Gender-related Development Index (GDI), which focuses on gender inequities that influence human capabilities in education, health and economic performance, but excludes several equity issues related to sustainable development, including time use, political participation and social institutions (UNDP, 1995; Fukada-Parr, 2003). There is also a UNDP Gender Equity Index (GEI) that considers three areas: (i) gender differences in income and employment; (ii) educational attainment; and (iii) gender gaps in parliament, senior executive and highly-qualified jobs (White, 1997). The Gender Gap Index (GGI) was developed by the World Economic Forum and includes indicators related to education, economic, political and health dimensions. This national-level index combines salary data, access to high-skilled employment, educational attainment, data on political representation, life expectancy and sex ratios, to create an index from 0 to 1, with 1 being no inequality (Haussman *et al.,* 2007). The Organisation for Economic Co-operation and Development (OECD) has developed the Social Institutions and Gender Index (SIGI), which assesses gender discrimination in law, norms and social institutions, in five different dimensions: discriminatory family code; restricted physical integrity; son bias, restricted resources and assets; and restricted civil liberties. The SIGI considers issues such as unequal inheritance rights, early marriage, violence against women, and unequal land and property rights and, unlike GGGI or GEI, a lower score indicates less discrimination against women (Jütting *et al.,* 2006, 2008). Finally, specific to agriculture is the Women's Empowerment in Agriculture Index (WEAI), a survey-based index that interviews both women and men to assess women's empowerment in decision-making about agricultural production, access to and decision-making about productive resources, control of and use of income, community leadership and time use (Alkire *et al.,* 2013). The WEAI has been tested and applied in numerous settings, providing evidence of links between women's empowerment and FSN outcomes in several countries, including Bangladesh, Ghana and Nepal (Malapit *et al.,* 2017; Sraboni *et al.,* 2014; Tsiboe *et al.,* 2018). It is considered a valid and relatively simple metric with potential use for research, policy and programmes that are interested in linkages between gender equity and agriculture (Alkire *et al.,* 2013).

Innovation and innovation systems in women's empowerment: Innovation systems that address women's empowerment may focus on ways to increase sharing and maintenance of knowledge, such as involving women in farmer research teams, participatory plant breeding, or increasing sharing of traditional knowledge of agrobiodiversity and food preparation (Galié, 2014; Humphries *et al*., 2012; Hoffmann, 2003; Belahsen *et al*., 2017; Stein *et al.*, 2018). Other innovation systems have focused on community initiatives to create dialogue and change in the gender division of labour within households (Bezner Kerr *et al.* 2016). Social movements that have mobilized around food sovereignty in Latin America have made significant gains in strengthening women's formal rights to land access, and increased women's share of land in Brazil and Bolivia (Deere, 2017). Farmer-led food sovereignty and agroecology initiatives in Latin America have included efforts to create more equitable family and community relationships (Oliver, 2017; Rosset *et al.,* 2011). Systematic reviews have found that women's empowerment has significant, positive impacts on women and children's nutrition (Carlson *et al.*, 2015; Cunningham *et al.,* 2015; Pratley, 2016). A review of the evidence for women's empowerment on food security outcomes found that innovations related to increasing women's access and control over natural resources such as seeds, land and communal land, combined with rights-based education, can have significant gains for FSN (Linares, 2009; Sraboni *et al.,* 2014). A cross-sectional study of over 4 000 households in Ghana found significant positive relationships between measures of women's empowerment in income, food production and leadership and food-security outcomes (Tsidoe *et al.,* 2017). Similar positive relationships were found in the United Republic of Tanzania, Benin, Nicaragua, Bangladesh and South Africa, among others (Mason *et al.,* 2015; Alaofè *et al.,* 2017; Schmeer *et al.*, 2015; Sharauanga *et al.,* 2016; Sraboni *et al.,* 2014). Creating more equitable access to market opportunities for women, through cooperatives, seed banks or other social mechanisms, is another innovation system with implications for FSN (Oumer *et al.,* 2014; Linares, 2009; Naughton *et al.,* 2017). Some markets, such as those with local, embedded relationships between producers and consumers, were more effective at addressing FSN (Ávila, 2011; Naughton *et al.,* 2017). One key dimension of increased income opportunities for women involved addressing unequal power dynamics around the control of income from food production, through community-based dialogue, women in leadership roles in cooperatives and education on rights (Bezner Kerr *et al.,* 2016; Naughton *et al.,* 2017). Addressing conflict between men and women related to income decision-making and control was a critical dimension to ensure positive food-security outcomes (Hebo, 2014). Increasing opportunities for women's access to and sharing of food production knowledge was another way in which women's empowerment increased food-security outcomes (Galié, 2014; Humphries *et al*., 2012; Hoffmann, 2003; Belahsen *et al.*, 2017; Stein *et al.*, 2018).

Right to food

States have the duty, obligation and responsibility to realize human rights, including the right to food, under international law. The International Covenant on Economic, Social and Cultural Rights (ICESCR) (UN, 1966) established this obligation. Article 11 establishes the right to an adequate standard of living, including food, and the right to be free from hunger. Article 12 establishes the right of everyone to the enjoyment of the highest attainable standard of physical and mental health. States are obliged to respect the right to food by not taking any measures that prevent access to food; they must protect the right to food by ensuring that individuals are not deprived of access to adequate food, and they must proactively carry out activities that strengthen people's access to resources and means to ensure FSN. In cases where people are unable to enjoy the right to food, states are obliged to provide that right directly through food aid but should facilitate future self-reliance and food security (UNCESCR, 1999).

Innovation and innovation systems in right to food: Innovation systems related to the right to food are often focused on changing state laws, policies and programmes to ensure equal access to food. Many state-based ”right to food” initiatives have focused on social assistance to those without secure access to food (Claeys, 2015). Some groups link the right to food to structural factors that affect people's access and control over food, such as trade rules or access to land (Claeys, 2015). In India, the constitution guarantees the protection of life and requires the state to raise the level of nutrition of all citizens. In 2001, civil society groups went to court to demand that the right to food for all citizens be recognized, and their case was upheld by the Supreme Court. As a result, the various food, social-security and livelihood programmes enacted by the state have become a legal entitlement rather than a benefit programme, and new programmes have been instituted to monitor these programmes for compliance. In addition, school-meal programmes have been mandated to use local, hot prepared meals, and to focus in particular on those most vulnerable to food insecurity (Mander, 2012).

Food justice

Food justice is a concept and social movement approach arising out of the urban poor, forging important linkages to urban concerns with FSN. Food justice can be defined as ‘‘the struggle against racism, exploitation, and oppression taking place within the food system that addresses inequality's root causes both within and beyond the food chain’’ (Hislop, 2014). As a social movement, food justice fights against inequalities and asymmetries generated by the prevalent food systems to address FSN.

Principles or key aspects of food justice: Food justice approaches to addressing FSN include recognizing the importance of local food production, valuing marginalized groups' practices and knowledge such as people of colour in the United States' context, criticizing the hegemonic model of food, focusing on the proliferation of ultraprocessed foods and supporting alternative production and consumption models.

Innovation and innovation systems in food justice: Food justice approaches combine social innovations to addressing social inequities with sustainable food production at multiple points in the food system. Food justice innovations include social mobilization, new organizational models and forging networks to address systemic inequities. Worker food cooperatives, food worker efforts for fair wages and efforts to ban toxic pesticides that affect farmer worker health are food justice examples that link food sovereignty and food justice (Alkon, 2014). Several authors have noted strong conceptual links between food sovereignty and food justice, and pointed to agroecology and urban agriculture, led by marginalized groups, as ways to enact equitable food systems in urban contexts (Alkon and Mares, 2012; Chappell and Schneider, 2016; Heynen *et al.,* 2012, and see **Box 31).**

Box 31 Food justice and agroecology with young people in the United States of America

A number of organizations and related social movements in the United States of America connect agroecological approaches with efforts to address racial and other social inequalities (Fernandez *et al.,* 2013; White, 2018; Sbicca, 2018; Reese, 2019). These initiatives also draw on agroecological approaches to provide decent, meaningful employment and increased economic autonomy in urban low-income communities where youth employment opportunities are low (White, 2018; Sbicca, 2018). Food justice and food sovereignty are concepts linked by these movements to addressing systemic racism, low access to healthy, diverse food and youth unemployment. The Detroit Black Community Food Security Network (DBCFSN, 2018), for example, is a community-based, non-profit organization that works to build food security, food justice and food sovereignty for Detroit's African American residents. They have a seven-acre urban farm to grow food that increases access to healthy fruits and vegetables for low-income community members. They train young people how to grow food using agroecological methods. They also have a food cooperative owned by members, which seeks to provide both jobs and affordable healthy local food for the community. Alongside the agroecological training, production and sales, the organization undertakes awareness raising about systemic racism, and how agriculture can be a source of economic autonomy and liberation rather than oppression for young Black people (White, 2018).

B. Organic agriculture

Organic agriculture is a production system that relies on ecosystem management and does not allow the use of synthetic chemical inputs (inorganic fertilizers and pesticides). It relies on ecological processes and natural sources of nutrients (such as compost, crop residues and manure). It has been considered as an environmentally friendly and economically viable alternative to conventional agricultural production (Leifeld, 2012), reducing external input costs (Jouzi *et al.,* 2017). There are proscribed and prescribed practices and well-developed certification processes associated with price premiums for organic produce, although there may difficulties for some small-scale producers in developing countries to access them (Lyngbaek *et al*., 2002).

Recent reviews of current systems have shown conventional systems to have higher yields compared to diversified, organic systems in some contexts (Ponisio *et al..* 2015; Reganold and Wachter. 2016), with yield gaps ranging from 8 percent to 20 percent. However, two global reviews found on the contrary that diversified systems outperformed conventional systems in developing country contexts by as much as 80 percent (Badgley *et al..* 2007). The benefits of organic agriculture include greater biodiversity, higher soil organic matter and improved soil properties, but not necessarily yield (Gattinger *et al*., 2012). Since organic farming supports greater stability of soil properties in the long term and provides a strategy for farmers to enhance soil quality, the closure of the yield gap between organic and conventional farming can take a significant amount of time (Shrama *et al..* 2018). Recent modelling studies suggest that organic agriculture with sufficient legumes in the crop mix could provide food in a sustainable way for more than 9 billion people in 2050 and reduce the negative environmental impact of agriculture (Mülller *et al.,* 2017).

Principles of organic agriculture

In its Council Regulation (EC) N° 834/2007 (EC 2007), the European Commission lists its overall principles for organic agriculture:

(a) the appropriate design and management of biological processes based on ecological systems using natural resources that are internal to the system;

(b) the restriction of the use of external inputs;[56]
(c) the strict limitation of the use of chemically synthesized inputs to exceptional cases (see also Migliorini and Wezel, 2017);[57]
(d) the adaptation, where necessary, of the rules of organic production as per the EC Regulation Nº 834/2007 taking account of sanitary status, regional differences in climate and local conditions, stages of development and specific husbandry practices.

Previously the International Federation of Organic Agriculture Movements (IFOAM) had based organic agriculture on four principles:[58]

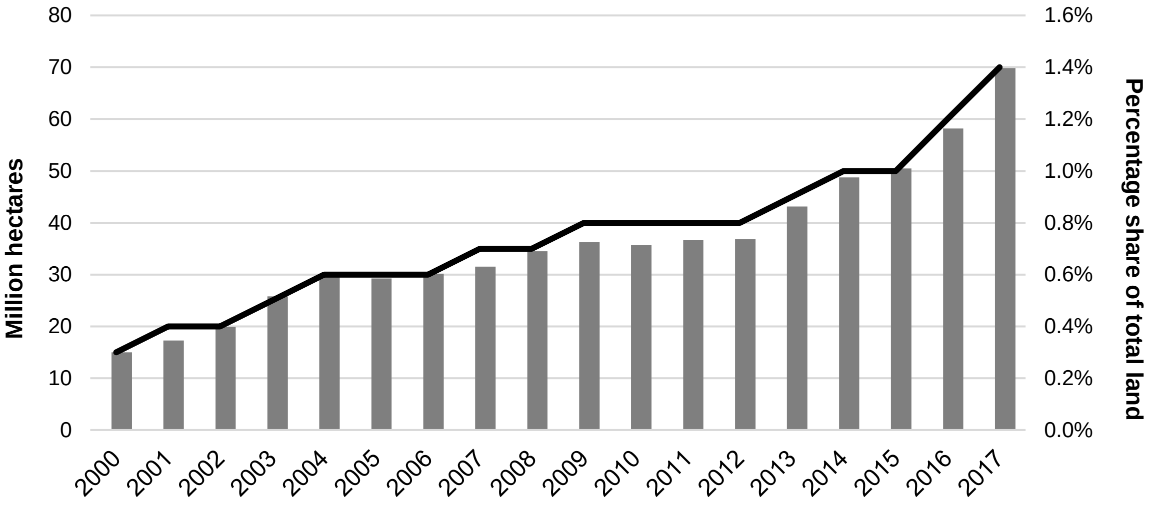
(a) health (soil, plant, animal, human and planet as one and indivisible);
(b) ecology (be based on living ecological systems and cycles, work with them, emulate them and help sustain them);
(c) fairness (with regard to the common environment and life opportunities);
(d) care (managed in a precautionary and responsible manner) to protect the health and well-being of current and future generations and the environment (IFOAM, 2014; Migliorini and Wezel, 2017).

These principles were then condensed in 2005 when the General Assembly of IFOAM passed a motion to establish a more compact definition of organic agriculture, eventually adopted in Adelaide, Australia:

"Organic Agriculture is 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 promote fair relationships and a good quality of life for all involved." [59]

Organic agriculture is on the rise globally (Willer and Lernoud, eds, 2019). The figures below clearly show the trend:

Figure 11 Evolution of the global organic agricultural land (2000-2017)



Source: FiBL and IFOAM 2019. See also: https://statistics.fibl.org/world/key-indicators-world.html

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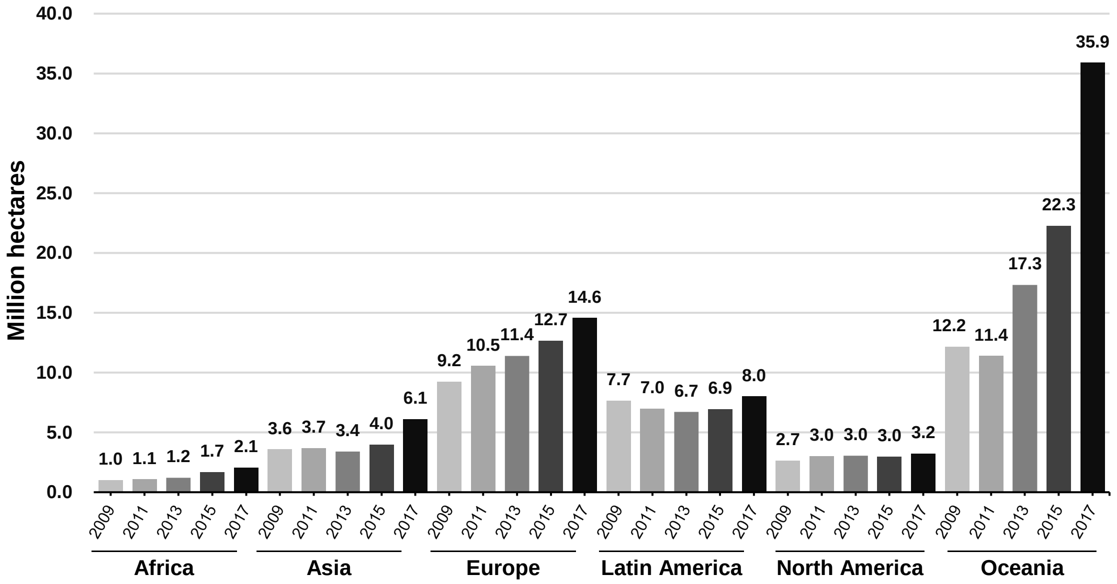
[56] Where external inputs are required or the appropriate management practices and methods do not exist, they shall be limited to: (i) inputs from organic production; (ii) natural or naturally-derived substances; (iii) low solubility mineral fertilizers.

[57] Exceptions include: (i) where the appropriate management practices do not exist; (ii) if the external inputs referred to in paragraph (b) are not available on the market; or (iii) where the use of external inputs referred to in paragraph (b) contributes to unacceptable environmental impacts.

[58] See https://www.ifoam.bio/sites/default/files/poa_english_web.pdf

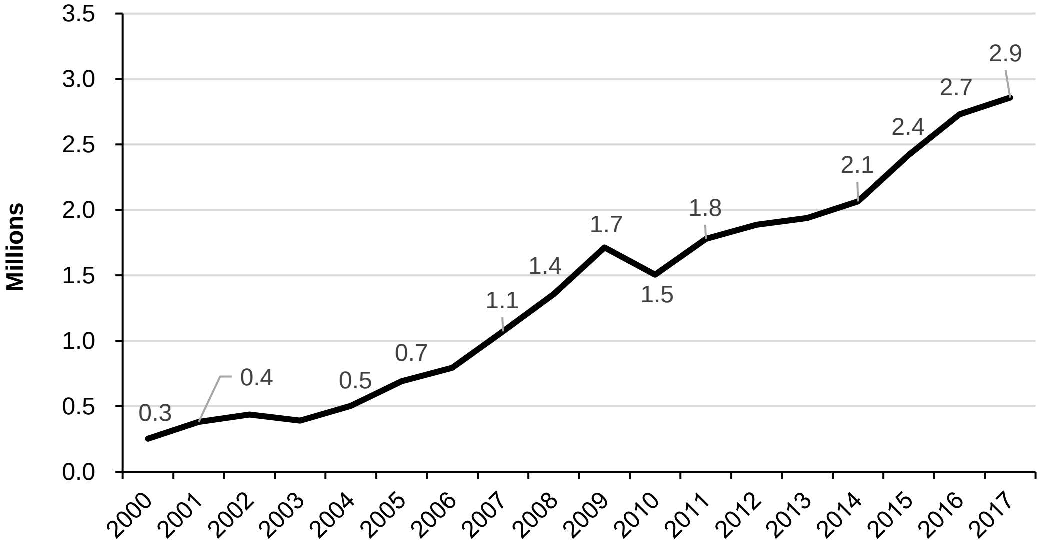
[59] See https://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture

Figure 12 Growth of the organic agricultural land by continent (2009-2017)



Source: FiBL and IFOAM 2019. See also: https://statistics.fibl.org/world/key-indicators-world.html

Figure 13 Development of the number of organic producers in the world (2000-2017)



Source: FiBL and IFOAM 2019. See also: https://statistics.fibl.org/world/key-indicators-world.html

C. Agroforestry

Agroforestry is where trees interact with agriculture (Sinclair, 2004). This may occur on field, farm, livelihood, landscape or global scales and represents an approach to achieving sustainable development of agriculture and improved nutrition through harnessing ecosystem services provided by trees (van Noordwijk *et al.,* 2018). Major types of agroforestry include silvo-arable (trees in crop fields), silvopasture (trees in pastures), companion trees or agricultural crops in perennial tree-crop production systems (such as coffee, cocoa, tea, rubber, oil palm and coconut), agriculture in forests (including forest grazing and deliberate and controlled exploitation of non-timber forest products), multi-strata production practices (including home gardens), woodlots on farms, and various other ways that trees in agricultural landscapes impact agriculture and rural people's livelihoods (Sinclair, 1999).

Principles of agroforestry: The key principle underlying agroforestry practice is that harnessing ecosystem services provided by trees integrated in agricultural systems can maintain high levels of productivity without causing environmental degradation (Anderson and Sinclair, 1993) and even restore degraded land (Crossland *et al.*, 2018). This has both ecological and economic dimensions associated with more functionally diverse production practices leading to greater resilience (Dumont *et al.*, 2017), reconciling the achievement of the UN Sustainable Development Goals (SDGs) 1 and 2 (to end poverty and hunger) with protection of the environment (SDG 14). Specific mechanisms include tighter nutrient- and water-cycling, higher abundances and activity of beneficial soil organisms (Barrios *et al*., 2012), climate buffering maintaining crop yields (Rahn *et al*., 2018; Sida *et al.,* 2017), higher carbon storage in vegetation and soil (Mbow *et al.,* 2014b); and tree products diversifying income and diet (Dawson *et al.,* 2013). The control and use of trees are often gender-specific and gender inequality is often a major constraint to agroforestry development, creating increasing interest in gender transformative actions (Baxter, 2018)

Innovation: From the outset of agroforestry science four decades ago, local knowledge has been recognized as a key resource because, while there was sparse scientific knowledge about tree–crop–animal interactions, there was a rich body of experience among farmers who had been incorporating trees in their agricultural systems, sometimes over many generations and at others in response to contemporary drivers of change (Sinclair and Walker, 1999). This emphasis on the importance of local knowledge has persisted with continued methodological innovation on bridging across the knowledge systems of scientists, farmers and policy-makers (Cerdan *et al.*, 2012; Dumont *et al.*, 2018a, 2018b). Early on in the evolution of the agroforestry paradigm a strong emphasis on participatory research to understand farmer requirements (Raintree, 1987) was coupled with controlled experiments on research stations to understand ecological interactions (Ong and Huxley, eds, 1996). More recently these have been brought closer together as a research ”in” rather than ’”for” development paradigm, in which research is embedded in development praxis (Coe *et al.*, 2014). It is achieved by moving away from widespread promotion of one or two iconic tree species and practices towards stakeholder engagement, structured by local knowledge acquisition, to identify a more diverse and inclusive range of species and practices that can be locally adapted (Dumont *et al.*, 2017). The adaptation is supported and made efficient through the use of co-learning methods in which planned comparisons involving large numbers of farmers trying out different options across a range of contexts are built into the scaling-up activities of development initiatives (Coe *et al.*, 2017). The approach is facilitated through multi-stakeholder innovation platforms and supported by modelling of livelihood trajectories to assess the likelihood of options resulting in transformative change if adopted in different contexts (Sinclair, 2017).

D. Permaculture

Permaculture aims at designing productive systems where structural and functional patterns of nature are the main guiding principles (Baldwin, 2005). It can also be defined as a philosophy of *working with nature*, taking into consideration that natural ecosystems are intrinsically complex, as opposed to conceptualizing any agricultural system with simplistic perspectives (Baldwin, 2005; Mollison, 1988). The term “permaculture” was expanded to two other expressions – *permanent culture* and *permanent agriculture* – in a broad comprehension that social values are imperatives for food systems, and also that all forms of doing agriculture are inevitably embedded in cultural values.

The concept of permaculture also encompasses landscape design, integrated water resources management, sustainable architecture and the whole concept of developing regenerative and self-maintained habitats (Holmgren, 2002, 2013). Originally proposed by Bill Mollison, an ecologist from Australia and professor at the University of Tasmania, and his graduate student David Holmgren in the 1970s, based on their observation of nature, permaculture is currently spread all over the world (Ferguson and Lovell, 2014). There are many permaculture centres in different countries and on all continents (**Box 11**).

Principles of permaculture: Permaculture systems are based on three core tenets and twelve design principles (Mollison, 1988; Holmgren, 2002). The core tenets are:

- care for the Earth;
- care for the people;
- fair share: govern our needs and return surplus and waste back into the system.

Permaculture can be categorized as one of the multiple schools of alternative agriculture under the encompassing concept of agroecology (Guzmán and Woodgate, 2013) proposing an ethical relationship between humans and the environment (Veteto and Lockyer, 2008; Holmgren, 2002; Ferguson and Lovell, 2015). Similar to agroecological approaches of designing and managing agroecosystems, permaculture is essentially based on using ecological principles to produce food. Some of these principles are related to minimizing energy and water use, integrating livestock and crops, recycling nutrients, avoiding chemical inputs such as pesticides and fertilizers, maximizing biodiversity and improving soil health (Hathaway, 2016). The concept of designing whole production systems based on a holistic approach emphasizing landscape patterns, functionality and species assembly represents a progress towards SFSs. The permaculture principles are very explicit in creating synergies among its constitutive elements – plants, animals, soil, climate, human labour and knowledge – maximizing useful connections and collaboration rather than competition.

E. Sustainable intensification

The use and occurrence of the term *sustainable intensification* have increased in scientific publications since 2009 and very significantly since 2013. It was initially defined by Pretty *et al.* (1996) and Pretty (1997) as:

“substantial growth of yields in currently unimproved or degraded areas while at the same time protecting or even regenerating natural resources”.

FAO, 2011 describes sustainable crop production intensification as *“producing more from the same area of land while conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services”.*

Although the sustainable intensification dialogue has been embraced by most international and national research and policy organizations as an aspiration, the articulation of its principles has been made by many actors and is not always consistent (Wezel *et al.,* 2015). This has been met with some criticism that its actual dimensions are hard to pin down and can be used by industrial agricultural intensification proponents to continue “business as usual” (Loos *et al.,* 2014). It has been suggested that proponents of sustainable intensification need to clarify how it diverges from industrial agriculture, address the problems of indiscriminate intensification itself, and devote more attention to trade-offs (Kuyper and Struik, 2014).

Principles of sustainable intensification that have been clearly elaborated include:

- Increase production with as little additional land conversion as possible and increased use of renewable resources such as labour, light and knowledge (Flavell, 2010; Godfray *et al.,* 2010; Pretty *et al.;* 2011; Firbank *et al.,* 2013).
- Increase resource use efficiency and optimize application of external inputs (FAO, 2011; Bos *et al..* 2013; Friedrich *et al.,* 2012; Matson *et al.,* 1997; McCune *et al.,* 2011; Pretty 1997, 2007).
- Minimize direct negative environmental impacts of food production (Royal Society, 2009; Pretty *et al.,* 2011; Firbank *et al.,* 2013).
- Close yield gaps on underperforming existing agricultural lands (Bos *et al.,* 2013; Garnett *et al.,* 2013; Mueller *et al.,* 2012).
- Improve the utilization of crop varieties and livestock breeds (Carswell, 1997; McCune *et al.,* 2011; Pretty, 2007; Ruben and Lee, 2000).
- Change human diets, reduce food wastes (Bos *et al.,* 2013; Garnett *et al.,* 2013) and deliver productivity gains in ways that are socially acceptable (Garnett *et al.,* 2013) are also objectives mentioned although not consistently.

Specific practices promoted within sustainable intensification include microdosing of synthetic fertilizer, precision agriculture, soil testing, soil conservation, seed spacing, water conservation practices, conservation tillage, improved crop rotations and applying living and residual mulches to cover the soil; use of legumes, cover crops and catch crops in rotations, and alley cropping, agroforestry, and integrated pest management; plant breeding, hybridization, biofortification, marker added selection, tissue culture, recombinant DNA, livestock cross-breeding, artificial insemination, and embryo transfer as well as inclusive agri-business chains, micro insurance, agricultural finance, value chains, agricultural cooperatives, and training, education and extension (Wezel *et al*., 2015; Kuyper and Struik, 2014; Montpellier Panel, 2013). Also specifically mentioned are use of worm composts, on-farm mechanization, precision technologies for irrigation and nutrient-use efficiency, use of high-yielding varieties including transgenic crops, and animal crop-integration.

Innovation: Innovative approaches in sustainable intensification are oriented towards the perceived imperative to address hunger and malnutrition through increasing productivity, but in a departure from the past Green Revolution approaches, innovations are also aimed towards doing so with greater efficiency and fewer environmental impacts, and on circumscribed parcels of land (land-sparing as opposed to land-sharing). Sustainable intensification supports technological innovation largely arising from the scientific and research community, such as advanced breeding techniques and precision forms of applying inputs. A good example is the development of improved crop varieties that are resistant/tolerant to biotic and abiotic stresses. In terms of dissemination of innovations, sustainable intensification stresses the benefits of economic or productivity gain (Mockshell and Kamanda, 2017), and has strong ties to markets and market solutions, as a route to scale up its innovations.

F. Climate-smart agriculture

In recent years, the agricultural research and development thrust has shifted towards promotion of best practices that enhance both productivity and resilience of agricultural and natural ecosystem functions under the vagaries of climate change and variability. According to FAO (2010), climate-smart agriculture (CSA) refers to those technologies, practices and approaches that sustainably increase agricultural production while maintaining and improving the natural resource base. CSA embraces all three pillars of sustainable development (environmental, economic and social), and responds to growing demands for food, feed, fuel and fibre in a changing climate.

Principles of climate-smart agriculture: The concept of CSA is increasingly being recognized as a major entry point for adaptation due to its ”triple-win” pillars, which focus on:

i. addressing food-security challenges through sustainably increasing farm-level productivity;
ii. enhancing the adaptive capacity of farmers through building resilience; and,-
iii. spear-heading mitigation of greenhouse gases in agriculture where possible (FAO, 2010, Lipper *et al.,* 2014).

Under the “pillar” of productivity, CSA aims to increase crop yields, increase soil productivity potential, enhance incomes and reduce pressure on the environment. In this sense, the orientation is essentially the same as sustainable intensification; however, CSA distinguishes itself by stressing aspects related to climate change, through the remaining two “pillars”. Under the “pillar” of adaptation, CSA aims to reduce exposure to short-term risks, enhance adaptive capacity, strengthen resilience and enhance the provision and protection of ecosystem services. Under the “pillar” of mitigation, CSA aims to reduce greenhouse gas emissions, and reduce the contribution by agriculture to climate change (FAO, 2010; Lipper *et al.,* 2014)

Innovation: CSA is not a new single prescriptive approach nor is it a set of practices, but something that often requires site-specific assessments to identify suitable and context-specific production technologies and practices (Williams *et al.,* 2015). Drivers of climate-smartness are many and often vary along local biophysical gradients including those defined by climate and soils, as well as with socio-economic factors and the agricultural enterprise at the core. Similar to sustainable intensification, CSA practices and approaches are envisaged to take cognizance of contributions to sustainable management of the natural resource base and socio-ecological resilience (Lipper *et al.*, 2014). CSA, however, does not propose specific blueprints for implementation, but rather has a strong focus on technologies, policies and financing (Saj *et al.,* 2017). Scientific debate around climate change has focused on whether the three pillars of the approach can indeed be attained simultaneously, or if there are discrepancies between these objectives (Saj *et al.,* 2017).

G. Nutrition-sensitive agriculture

Nutrition-sensitive agriculture is a “food-based approach to agricultural development that puts nutritionally rich foods, dietary diversity, and food fortification at the heart of overcoming malnutrition and micronutrient deficiencies” (FAO, 2014a). The approach recognizes that nutritious food is essential for human development, acknowledges the social, cultural and economic significance of food and agriculture for rural communities, and nutrition education to help address health outcomes. It includes a range of strategies, including biofortification, homestead food production systems, aquaculture, dairy, livestock and irrigation programmes, value chains for nutritious foods, and observational studies (Ruel *et al.*, 2018). Increased attention at the policy level (e.g. FAO, 2013; World Bank, 2007) on the linkages between agriculture and nutrition over the last decade has led to a proliferation of research studies under way to implement nutrition-sensitive agriculture, often in association with attention to gender issues (Hawkes *et al.,* 2012; Ruel *et al*., 2018).

Innovation: Nutrition-sensitive approaches that most effectively address nutrition take questions of differential levels of agency of different vulnerable groups into account, including gender dynamics

(Ruel *et al*., 2013, Glover and Poole, 2019). Examples are the innovative social protection programmes that strengthen FSN for both producers and consumers through public policies, as occurred with the *Bolsa Familia* cash transfer programme in Brazil (Rocha, 2009; Chappell, 2018).

Increased education can improve FSN through multiple pathways, of which only a few have been empirically tested: teaching health and nutrition; teaching numeracy and literacy, which allows for increased learning of nutrition and agricultural information; exposing people to new ideas, which makes them willing to take risks with new technologies such as medicine; increasing self-confidence, which could then affect women's empowerment (Ruel *et al.,* 2013). Innovative educational strategies involving participatory methodologies have been used to integrate agriculture, social equity and nutrition with positive food-security, nutrition and sustainability outcomes (Bezner Kerr *et al*., 2010), but a key power dynamic to be considered in this case relates to community leaders and gatekeepers (Glover and Poole, 2019).

H. Sustainable food value chains

A sustainable food value chain (SFVC) is defined as "the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources" (FAO, 2014b). Value can be added to an intermediate agrifood product not only by processing it, but also by storing it (value increasing over time) and transporting it (value increasing over space, or also over time by "deseasonalizing" – making food products available, and thus more valuable, outside their season). A SFVC is an approach that has been put into practice by many initiatives of small farmers and the private sector around the world. VCs typically cover a country's entire product subsector (e.g. beef, maize or salmon).

Innovation: At present the least value is created at the production stage compared with other stages, in part due to the high concentration of both agro-inputs and food retail (IPES-Food 2016; Howard, 2016). The high input costs in industrial agriculture contribute to the problem for farmers, who often rely heavily on credit and risk-based insurance to offset the risks and instability of farm incomes. Farm income remains unstable and precarious for most farmers in industrial farming systems, with only large farms able to bear the high costs of industrial farming (IPES-Food, 2016). Improvements for sustainability of producers will depend on connections within the chain, and on the level of concentration within a given industry (Howard, 2016). Development of sustainable value chains with low-income smallholder farmers may thus require supporting farmer organizations and cooperatives in their capacity to build and negotiate more equitable markets (Bacon, 2010; FAO and INRA, 2018). These farmers may have the systems thinking needed for effective networking aspirations, but are constrained by time, resources and limited agency. Thus, innovations and dissemination depend on multi-stakeholder collaboration in the agrifood value chain, for collective achievement of competitive advantage for better environmental, business and societal outcomes. Inclusive business models are required to address equity concerns, which may include re-embedding markets into communities, participatory decision-making and specific inclusive initiatives, such as paying cash on delivery or accepting small consignments (FAO and INRA, 2018). A good governance structure is a critical element of sustainable VCs; it refers to the nature of linkage both between actors at particular stages in the chain (horizontal linkages) and within the overall chain (vertical linkages) (FAO, 2014b). A key innovation in SFVCs has been the emergence of participatory guarantee systems (PGS), an innovation in standards, in which the oversight system for certification is created through a democratic process involving producers, experts and consumers who ensure that the standards are acceptable to all (IFOAM, 2016) (**Box 32)**.

Box 32 Participatory Guarantee Systems

Participatory Guarantee Systems (PGS) refers to locally focused quality assurance mechanisms that certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange (IFOAM, 2013). Originally developed in Brazil as an alternative to third-party certification schemes for organic products, it rapidly spread around the world. Currently, there are PGS in more than 70 countries counting hundreds of local and regional schemes, particularly in South America (AgriCultures Network, 2016; IFOAM, 2013).[60] In many Latin American countries such as Bolivia, Brazil, Chile, Costa Rica, Mexico and Peru, government authorities officially recognize this certification system. Often, these types of systems are mentioned at the same time as organic and agroecological guarantee systems (Abreu *et al*., 2012; Boeckmann and Caporal, 2011). While external professionals base third-party organic certification on a review of applications and inspections, PGS endorse interactions among farmers and other stakeholders and use different mechanisms to build credibility. The whole process is based on social networks where all stakeholders – producers, small processing industries, retailers and consumers – share responsibility and active involvement to assure the quality of products. The collaborative governance helps to empower farmers and is also founded on solidarity and transparent connections. Some of the benefits of PGS include: improved access to organic markets, particularly for non-certified and agroecological farmers, excluded and socially vulnerable groups of farmers; increased education and awareness of consumers; incentives for short supply chains and local marketing endeavours; and empowerment of farmers and consumers as they own the conformity assessment system. Such innovation systems also have a number of positive aspects in promoting food security and nutrition. Better access to markets helps farmers to increase income and eventually sell some neglected and non-conventional products, thereby facilitating increased income. As the system is based on permanent exchanges among members where solidarity and trust are core values it facilitates the creation of safety networks preventing situations of food insecurity, and may contribute to empowerment of poor famers.

Freshveggies Participatory Guarantee Systems in Uganda

The Freshveggies Participatory Guarantee System in Uganda, which began in 2009, is a private agroecological production and marketing initiative, based on direct contact, trust and long-term relationships (FAO and INRA, 2018). The initiative was built on an existing women's savings and credit cooperative, and aims to promote healthy eating, viable incomes and sustainable production among its members. Over 80 food producers agreed on a list of internal production standards, and they receive ongoing training and have regular meetings to increase capacity in agroecological methods. Consumers can participate in the meetings, to ensure open dialogue and insight into the challenges for agroecological production. Consumers include over 80 individual households, local restaurants, organic shops, offices, farmers' markets and supermarkets. Producers earn on average USD200/month for six months from sales of vegetables through this effort, a significant additional resource for these low-income producers.

Sources: Abreu *et al.* (2012), Boeckmann and Caporal (2011), IFOAM (2013) and FAO and INRA (2018).

I. Collation of principles across innovative approaches

This section collates statements about principles from different approaches in a tabulated format (**Table 5**) that was used as the basis for deriving the combined principles (**Table 2**) in Chapter 2. Nutrition-sensitive agriculture and SFVCs are initiatives without a distinct and defined set of principles; however, their key points are well captured in the principles from other approaches set out in **Table 5**. CSA and sustainable Intensification are combined in this table for ease of presentation.

Table 5 Comprehensive set of principles of the different innovation approaches to FSN

Agroecological principles	Rights-based	Sustainable intensification + Climate-smart agriculture	Organic agriculture	Agroforestry	Permaculture
Recycling. Optimize the use of local renewable resources and close resource cycles of nutrients and biomass.		Minimize direct negative environmental impacts of food production. Increase production with little additional land conversion as possible and increased use of renewable resources such as labour, light and knowledge.	Appropriate design and management of biological processes based on ecological systems using natural resources that are internal to the system.	Trees in agricultural systems often fix nitrogen and tighten nutrient and water cycles..	Prioritizes recycling of nutrients, water and energy within systems.
Input reduction. Reduce or eliminate the dependency on external inputs.		Increase resource use efficiency and optimizing application of external inputs. Close yield gaps on underperforming existing agricultural lands. Improve the utilization of crop varieties and livestock breeds.	Restriction of the use of chemical inputs. Strict limitation on the use of chemically synthesized inputs to exceptional cases.		
Soil heath. Secure and enhance soil health for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.			Enhance soil health.	Trees in agricultural systems can increase the abundance and activity of beneficial soil organisms	Enhance soil health.
Animal health. Ensure animal health and welfare.			Guarantee animal health and welfare.	Tree shade can reduce heat stress in animals in hot conditions, reduce wind-chill in cold conditions and provide nutritious fodder at times when herbaceous plants cannot.	
Synergy. Enhance positive ecological interaction, synergy, integration and complementarities between the elements of agroecosystems (plants, animals, trees, soil, water).			Ecology (be based on living ecological systems and cycles, work with them, emulate them and help sustain them).	Niche differentiation between trees and crops provides huge scope to manage tree–crop combinations to exploit differences in resource capture in space and time.	Increase synergies between different parts of the system including plants, soil, water.
Diversity. Maintain and enhance diversity of species and genetic resources and maintain biodiversity in the agroecosystem over time and space at the field, farm and landscape levels.	Food sovereignty. Protection of natural resources.	Release land for wildlife conservation through producing more on agricultural land		Trees in agricultural systems increase both functional agrobiodiversity and niches for wildlife conservation.	Care for the Earth.
Diversification. Diversify on-farm incomes by giving small-scale farmers greater financial independence and value addition opportunities and enabling them to respond to the demands of consumers.				Products from trees on agricultural land can diversify farm income.	

Agroecological principles	Rights-based	Sustainable intensification + Climate-smart agriculture	Organic agriculture	Agroforestry	Permaculture
Co-creation of knowledge. Enhance co-creation and horizontal sharing of knowledge of local, indigenous, traditional and scientific knowledge and innovation, and especially farmer-to-farmer exchange.				Local agroecological knowledge is generally detailed, explanatory and largely complementary to scientific knowledge so that combined knowledge is richer than either alone.	
Social values and diets. Build food systems based on the culture, identity, tradition, social and gender equity, innovation and knowledge that include healthy, diversified, seasonally and culturally appropriate diets of local communities and livelihoods.	Food justice. Focus on the proliferation of ultraprocessed foods	Change diets to be more sustainable.		Use and control of tree resources are often gender-specific and gender inequality can be a major constraint to agroforestry development. Tree fruits can increase dietary diversity.	
Fairness. Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights.			Fairness (with regard to the common environment and life opportunities.		Care for the people.
Connectivity. Increase proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.	Food sovereignty. Reorganization of food trade to support local food production. Food justice. Recognize the importance of local food production	Supporting alternative production and consumption models.	-	-	
Land and natural resource governance. Recognize and support the needs and interests of family farmers, smallholders and peasant food producers as sustainable managers and guardians of natural and genetic resources.	Food sovereignty. Food as a basic human right. Reduction of multinational concentration of power. Increase democratic control of the food system. The need for agrarian reform. Food justice. Criticizing the hegemonic model of food.			Agroforestry policies that join up policy formulation and implementation across sectors and scales result in more rational and integrated land-use decision-making.	
Participation. Encourage social organization and greater participation and decision-making of food producers and consumers to support decentralized governance and local adaptive management of food and agricultural systems.	Food justice. Value marginalized groups' practices and knowledge.				

Agroecological principles	Rights-based	Sustainable intensification + Climate-smart agriculture	Organic agriculture	Agroforestry	Permaculture
Principles that do not fit into the structure above derived from the 13 consolidated principles of agroecology	Food sovereignty. Foster peace.	Adoption of climate-smart agricultural practices can increase adaptation to climate change by targeting specific climate hazards and/or improving resilience of livelihoods at the same time as sequestering carbon and reducing emission of greenhouse gases.	Care (managing land in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment).	Trees in agricultural systems can increase carbon storage directly in the trees themselves and through increasing soil carbon ,and contribute directly to adaptation through climate buffering and indirectly through contributing to livelihood resilience.	Setting limits to population and consumption.

A2 The HLPE project cycle

The High Level Panel of Experts for Food Security and Nutrition (HLPE) was created in October 2009 as the science–policy interface of the UN Committee on World Food Security (CFS).

The CFS is the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition (FSN), for a broad range of committed stakeholders to work together in a coordinated manner and in support of country-led processes towards the elimination of hunger and ensuring FSN for all human beings.[61]

The HLPE receives its working mandate from CFS. This ensures the legitimacy and relevance of the studies undertaken, and their insertion in a concrete political agenda at international level. The report elaboration process ensures the scientific inclusiveness and the independence of the HLPE.

The HLPE produces scientific, policy-oriented reports, including analysis and recommendations, serving as a comprehensive and evidence-based starting point for policy debates at CFS. The HLPE aims at providing a better understanding of the diversity of issues and rationales when dealing with food and nutrition insecurity. It thrives to clarify contradictory information and knowledge, elicit the backgrounds and rationales of controversies, and identify emerging issues.

The HLPE is not mandated to conduct new research. The HLPE draws its studies based on existing research and knowledge produced by various expertise-providing institutions (universities, research institutes, international organizations, etc.), adding value by global, multi-sectoral and multi-disciplinary analysis.

HLPE studies combine scientific knowledge with experiences from the ground, in the same rigorous process. The HLPE translates the richness and variety of forms of expert knowledge from many actors (knowledge of local implementation, knowledge based on global research and knowledge of "best practice") that draw on both local and global sources into policy-related forms of knowledge.

To ensure the scientific legitimacy and credibility of the process, as well as its transparency and openness to all forms of knowledge, the HLPE operates with very specific rules, agreed by the CFS.

The HLPE has a two-tier structure:

1. A Steering Committee composed of 15 internationally recognized experts in a variety of FSN related fields, appointed by the Bureau of CFS. HLPE Steering Committee members participate in their individual capacities, and not as representatives of their respective governments, institutions or organizations.
2. Project Teams acting on a project specific basis, selected and managed by the Steering Committee to analyse/report on specific issues.

The project cycle to elaborate the reports (**Figure 14**) includes clearly defined stages, starting from the political question and request formulated by the CFS. The HLPE institutes a scientific dialogue, building upon the diversity of disciplines, backgrounds, knowledge systems, the diversity of its Steering Committee and Project Teams, and open e-consultations. The topic-bound and time-bound Project Teams work under the Steering Committee's scientific and methodological guidance and oversight.

The HLPE runs two open consultations per report: first, on the scope of the study; second, on a V0 "work-in-progress" draft. This opens the process towards all experts interested as well as to all concerned stakeholders, who are also knowledge-holders. Consultations enable the HLPE to better understand the issues and concerns, and to enrich the knowledge base, including social knowledge, thriving for the integration of diverse scientific perspectives and points of view.

It includes an external scientific peer-review on a pre-final draft. The report is finalized and approved by the Steering Committee during a face-to-face meeting.

HLPE reports are published in the six official languages of the UN (Arabic, Chinese, English, French, Russian and Spanish), and serve to inform discussions and debates in CFS.

All information regarding the HLPE, its process and all former reports are available on the HLPE Website: www.fao.org/cfs/cfs-hlpe

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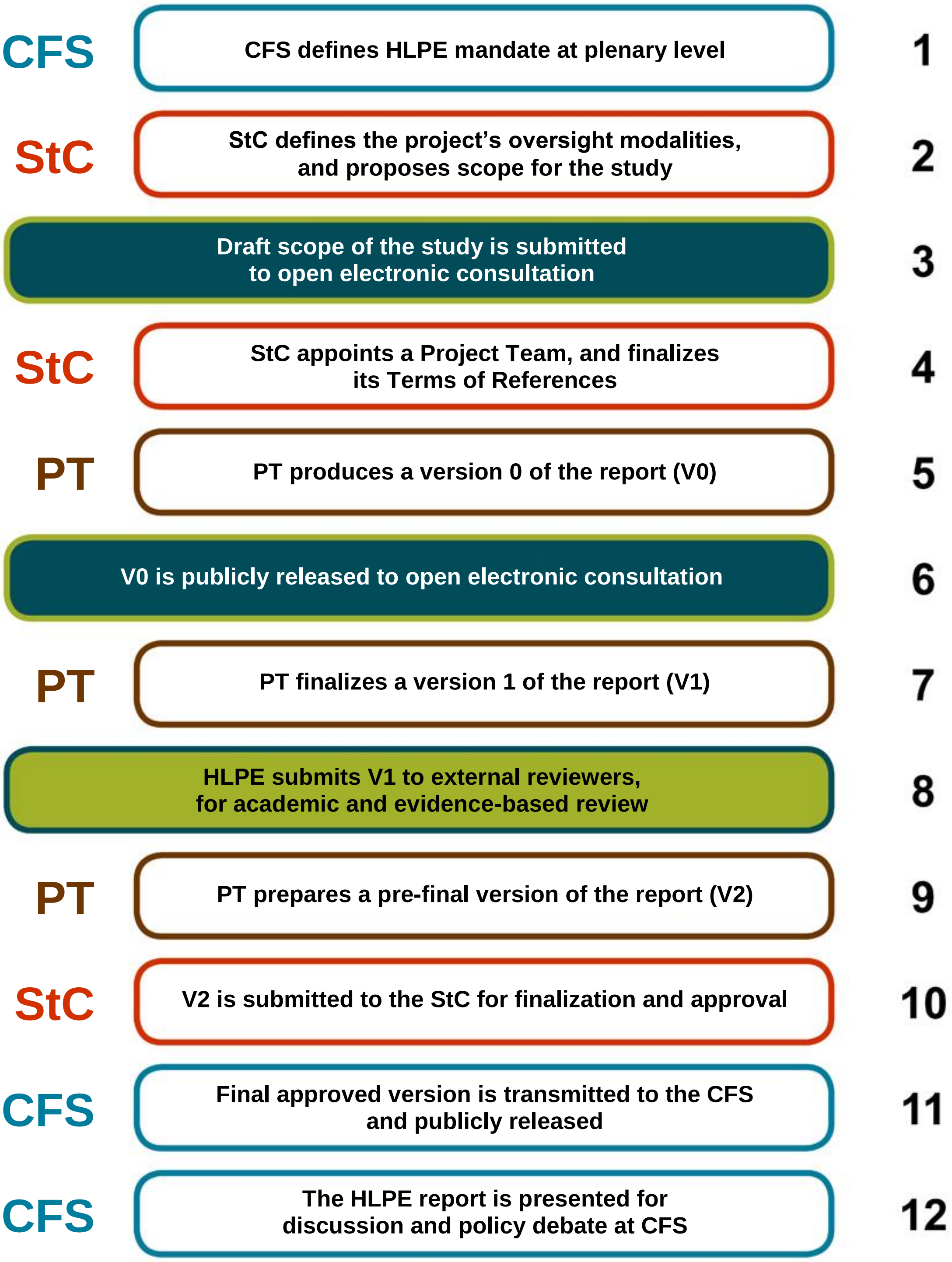
[61] CFS Reform Document, available at www.fao.org/cfs

Figure 14 HLPE project cycle



CFS	Committee on World Food Security
HLPE	High Level Panel of Experts on Food Security and Nutrition
StC	HLPE Steering Committee
PT	HLPE Project Team

Front cover photo: © CIFOR/Tri Saputro
Back cover photo: ©FAO/Veejay Villafranca

Food systems and agriculture are at a crossroads and a profound transformation is needed at all scales, not only to achieve Sustainable Development Goal 2 (SDG2) to "end hunger and all forms of malnutrition" by 2030 but also to address Agenda 2030 in its entirety, including human and environmental health, climate change, equity and social stability. Current trends, such as the new increase, since 2014, in the number of undernourished people and the alarming rate of all forms of malnutrition in all countries, and related tensions will be exacerbated if we fail to design and implement, in a very near future, food systems that ensure food security and nutrition while addressing all sustainability challenges. Agroecological and other innovative approaches in agriculture are increasingly praised for their potential contribution to reach these crucial goals. This report adopts a dynamic perspective, centred on the key concepts of transition and transformation. Ultimately, this rich and comprehensive report aims to fuel an exciting policy convergence process and help remove the lock-ins by developing a common understanding of these matters, so that concrete transition pathways can be implemented at all relevant scales, from farm, community and landscape to national, regional and global levels.

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