Committee on World Food Security

High Level Panel of Experts on Food Security and Nutrition

Agroecological approaches and other innovations for sustainable agriculture and food systems that enhance food security and nutrition

V0 DRAFT REPORT

4 October 2018

Submitted by the HLPE to open electronic consultation

until 5 November 2018

This V0 draft is publicly available on the HLPE consultation platform:

http://www.fao.org/fsnforum/cfs-hlpe/discussions/agroecology_innovation-v0

Please read the consultation cover letter on pages 2 and 3 of this document

Comments can be sent by e-mail to: cfs-hlpe@fao.org or to fsn-moderator@fao.org.

This consultation will be used by the HLPE to further elaborate the report, which will then be submitted to peer review, before its finalization and approval by the HLPE Steering Committee.

DISCLAIMER

HLPE V0 drafts are deliberately presented early enough in the process - as a work-in-progress, with their range of imperfections – to allow sufficient time to give proper consideration to the feedback received so that it can play a really useful role in the elaboration of the report. It is a key part of the scientific dialogue between the HLPE Project Team and Steering Committee, and the rest of the knowledge community.

This V0 draft may be thoroughly corrected, modified, expanded and revised after the present consultation.

In order to strengthen this draft, the HLPE would welcome submission of material, evidence-based suggestions, references, and examples, in particular addressing the important questions in the cover letter (pages 2 and 3).

For this reason we kindly invite you not to cite nor quote elements from this V0. ***Please only refer to the final publication for quotations.***

Figures are intended as placeholders and will not be reproduced as they are in the final publication. Do not copy or quote.

COVER Letter from the HLPE to this V0 Consultation

Agroecological approaches and other innovations for sustainable agriculture and food systems that enhance food security and nutrition

During its 44th Plenary Session (9-13 October 2017), the 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 be presented at CFS 46th Plenary session in October 2019.

As part of the process of elaboration of its reports, the HLPE is organizing a consultation to seek inputs, suggestions, and comments on the present preliminary V0 draft (for more details on the different steps of the process, see the Appendix in the V0 draft). The results of this consultation will be used by the HLPE to further elaborate the report, which will then be submitted to external expert review, before finalization and approval by the HLPE Steering Committee.

HLPE V0 drafts prepared by the Project Team are deliberately presented early enough in the process - as a work-in-progress, with their range of imperfections – to allow sufficient time to give proper consideration to the feedbacks received so that it can play a really useful role in the elaboration of the report. It is a key part of the inclusive and knowledge-based dialogue between the HLPE Project Team and Steering Committee, and the whole knowledge community.

In that respect, the present V0 draft identifies areas for recommendations at a very early stage, and the HLPE would welcome suggestions or proposals. In order to strengthen the report, the HLPE would welcome submission of material, evidence-based suggestions, references, and concrete examples, in particular addressing the following important questions:

1. The V0 draft is wide-ranging in analyzing the contribution of agroecological and other innovative approaches to ensuring food security and nutrition (FSN). Is the draft useful in clarifying the main concepts? Do you think that the draft appropriately covers agroecology as one of the possible innovative approaches? Does the draft strike the right balance between agroecology and other innovative approaches?

2. Have an appropriate range of innovative approaches been identified and documented in the draft? If there are key gaps in coverage of approaches, what are these and how would they be appropriately incorporated in the draft? Does the draft illustrates correctly the contributions of these approaches to FSN and sustainable development? The HLPE acknowledges that these approaches could be better articulated in the draft, and their main points of convergence or divergence among these approaches could be better illustrated. Could the following set of "salient dimensions" help to characterize and compare these different approaches: human-rights base, farm size, local or global markets and food systems (short or long supply chain), labor or capital intensity (including mechanization), specialization or diversification, dependence to external (chemical) inputs or circular economy, ownership and use of modern knowledge and technology or use of local and traditional knowledge and practices?

3. The V0 draft outlines 17 key agroecological principles and organizes them in four overarching and interlinked operational principles for more sustainable food systems (SFS): resource efficiency, resilience, social equity / responsibility and ecological footprint. Are there any key aspects of agroecology that are not reflected in this set of 17 principles? Could the set of principles be more concise, and if so, which principles could be combined or reformulated to achieve this?

4. The V0 draft is structured around a conceptual framework that links innovative approaches to FSN outcomes via their contribution to the four abovementioned overarching operational principles of SFS and, thus, to the different dimensions of FSN. Along with the four agreed dimensions of FSN (availability, access, stability, utilization), the V0 draft also discusses a fifth dimension: agency. Do you think that this framework addresses the key issues? Is it applied

appropriately and consistently across the different chapters of the draft to structure its overall narrative and main findings?

5. The V0 draft provides an opportunity to identify knowledge gaps, where more evidence is required to assess the contribution that agroecology and other innovative approaches can make progressing towards more sustainable food systems for enhanced FSN. Do you think that the key knowledge gaps are appropriately identified, that their underlying causes are sufficiently articulated in the draft? Is the draft missing any important knowledge gap? Is this assessment of the state of knowledge in the draft based on the best up-to-date available scientific evidence or does the draft miss critical references? How could the draft better integrate and consider local, traditional and empirical knowledge?
6. Chapter 2 suggests a typology of innovations. Do you think this typology is useful in structuring the exploration of what innovations are required to support FSN, identifying key drivers of, and barriers to, innovation (in Chapter 3) and the enabling conditions required to foster innovation (in Chapter 4)? Are there significant drivers, barriers or enabling conditions that are not adequately considered in the draft?
7. A series of divergent narratives are documented in Chapter 3 to help tease out key barriers and constraints to innovation for FSN. Is this presentation of these divergent narratives comprehensive, appropriate and correctly articulated? How could the presentation of the main controversies at stake and the related available evidence be improved?
8. This preliminary version of the report presents tentative priorities for action in Chapter 4, as well as recommendations to enable innovative approaches to contribute to the radical transformations of current food systems needed to enhance FSN and sustainability. Do you think these preliminary findings can form an appropriate basis for further elaboration, in particular to design innovation policies? Do you think that key recommendations or priorities for action are missing or inadequately covered in the draft?
9. Throughout the V0 draft there has been an attempt to indicate, sometimes with placeholders, specific case studies that would illustrate the main narrative with concrete examples and experience. Are the set of case studies appropriate in terms of subject and regional balance? Can you suggest further case studies that could help to enrich and strengthen the report?
10. Are there any major omissions or gaps in the V0 draft? Are topics under-or over-represented in relation to their importance? Are any facts or conclusions refuted, questionable or assertions with no evidence-base? If any of these are an issue, please share supporting evidence.

We thank in advance all the contributors for being kind enough to read, comment and suggest inputs on this V0 draft of the report. We look forward to a rich and fruitful consultation.

The HLPE Project Team and Steering Committee

HLPE Project Team

Project Team Leader: Fergus Lloyd Sinclair (United Kingdom)
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), Alexander Wezel (Germany).

HLPE Steering Committee

Chairperson: Mr Patrick Caron (France), **Vice-Chairperson:** Mr Mahmoud El Solh (Lebanon),
Steering Committee Members: Mr Martin Cole (Australia), Ms Louise O. Fresco (the Netherlands), Mr Alex Godoy-Faúndez (Chile), Ms Maria Kadlečíková (Slovakia), Ms Eileen Theresa Kennedy (United States of America), Mr Muhammad Khan (Pakistan), Mr Xiande Li (People’s Republic of China), Mr Paul Mapfumo (Zimbabwe), Mr Mohammad Saeid Noori Naeini (Islamic Republic of Iran), Ms Elisabetta Gioconda Iole Giovanna Recine (Brazil), Ms Shiney Varghese (India), Mr Martin Yemefack (Cameroon), Mr Rami Zurayk (Lebanon).

Experts participate in the work of the HLPE in their individual capacities, and not as representatives of their respective governments, institutions or organizations

Contents

List of Figures

List of Definitions

List of Tables

List of Boxes

FOREWORD

To be developed.

SUMMARY AND RECOMMENDATIONS

Summary

To be developed

Recommendations

This section of the report is presented now only as a very preliminary draft. It will be discussed during the next HLPE Steering Committee in November. It presents broad areas for possible recommendations and will be further developed in the next iterations, in light of contributions from the open consultation.

Major changes in policy, investment, education and training are required to support innovation that will achieve FSN globally. While there are steps being taken in appropriate directions in many countries, there is an urgent imperative for them to be extended and accelerated if SDG 2 to end hunger, achieve food security and improved nutrition and promote sustainable agriculture, is to be achieved by 2030.

1. INCREASE INVESTMENT IN SMALL AND MEDIUM SIZED AGRICULTURAL AND FOOD ENTERPRISES

States, local governments and the private sector should review the current policy and investment climate that in many contexts favours economies of scale associated with larger farm and business sizes to consider the public advantages attainable through maintaining smaller, more labor intensive units that have positive social impacts and fewer negative environmental externalities. Specifically they should:

a) Increase public investment in support of small and medium-sized farms that currently provide the majority of the food supply. For example by shifting agricultural subsidies to be based on holistic indicators of sustainable food systems (SFSs) (see recommendation 2) that support development of diversified farming systems and multifunctional landscapes.

b) Support value chain innovation platforms that encourage private sector actors to participate in upgrading food value chains by investing in and rewarding socially and environmentally sustainable small and medium sized farm producers and aggregation mechanisms.

c) Support, through provision of financing mechanisms, the creation of a green economy, especially supporting young entrepreneurs, women and community enterprises that capture and retain value in rural localities.

2. RECONFIGURE AND INTEGRATE EDUCATION, TRAINING AND RESEARCH ON SUSTAINABLE AGRICULTURE FOR FSN

States, local authorities, academic institutions, INGOs, NGOs and civil society should encourage knowledge generation and sharing, education and training that are integrated and respond to community needs and priorities for SFSs for FSN. Specifically they should:

a) Redesign primary, secondary school and university curricula to include SFSs for FSN which integrate hands-on experiential learning.

b) Ensure training programs for agricultural extension and public health workers promote sustainable food production for FSN.

c) Increase public investment in research and development programs in agro-ecological and other approaches towards more SFSs for enhanced FSN, including through the CGIAR and national systems.

d) Support the integration of agricultural research with development praxis to strengthen capacity of development initiatives to address local needs, generate evidence on the performance of sustainable agricultural options in real world contexts and focus research on development imperatives as experienced in the implementation of SFSs for FSN.

e) Create networks of "lighthouses" or innovation platforms that foster farmer-to-farmer knowledge sharing and create communities of practice.

f) Develop practical, scientifically grounded methods for assessing SFSs for FSN using appropriate metrics and indicators that, in particular, capture ecological footprints and nutritional outcomes.

3. RECOGNISE THE ROLE OF POLICY OVER ACCESS TO NATURAL RESOURCES

Sates and local authorities should:

a) Provide 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 the CFS in 2012.

b) Address access to land and land tenure, especially for young people, women and socially marginalised people, including regulation of large-scale land acquisitions where appropriate.

c) Develop or reform national and regional seed legislation and intellectual property legislation to support the informal exchange and access to diverse, traditional seed varieties.

4. SUPPORT EQUITABLE AND SUSTAINABLE FOOD VALUE CHAINS

States, local authorities and private sector actors should:

a) Strengthen local authorities' (e.g. municipalities) capacity to design local policies that support diversified, sustainable, equitable markets that enhance connections between producers and consumers.

b) Provide public facilities to host farmers markets, fairs and festivals for agrocological and other diversified sustainable local producers.

c) Facilitate the registration of agroecological and other sustainable food producers with trade and food safety authorities that accommodate their size and production capacity.

d) Support the creation of viable farmer associations, that share knowledge and create strong networks to leverage required inputs (including alternative inputs, such as cover crop seed).

e) Recognize participatory guarantee systems (PGS) as a valid means to certify organic, ecological and agro-ecological producers for local and domestic markets, which are often most feasible for low-income, small-scale producers to access.

5. LEVERAGE PUBLIC PROGRAMS TO FOSTER SUSTAINABLE FOOD SYSTEMS FOR FSN

States and local authorities should:

a) Design and implement innovative social protection programs that strengthen FSN for both producers and consumers through public policies.

b) Integrate nutrition sensitive agriculture into sustainable agricultural development policies and programmes, including for example the promotion of home gardens with micronutrient-rich legumes, vegetables and tubers, small livestock such as poultry, or programmes with an explicit focus on nutrition education and gender equity.

c) Develop domestic policies on rights to food that domesticate the international covenants and agreement establishing this obligation; this may mean making food security programmes into legal entitlements rather than social benefit programmes.

d) Use public procurement, including for school nutrition, as an avenue to address food security and better nutrition and forge linkages with agro-ecological producers.

e) Collect more accurate data on the amount and location of food losses and waste, and strategies to reduce these, with the involvement and collaboration of all stakeholders along the supply chain.

•

6. FOSTER DEMOCRATIC AND PARTICIPATORY APPROACHES FOR POLICY DEVELOPMENT AND IMPLEMENTATION

States should ensure that marginalized groups (e.g. small-scale smallholder farmers, farm and estate workers, women, young people, indigenous groups and low-income urban dwellers) have a voice in the development of policy relating to SFS for FSN through methods such as:

a) Territorial management planning to identify relevant ecological practices, protection of common areas for water, forest and other resources at a regional level. This should include development of policy processes and social capital at local landscape scales so that policies can be implemented through inclusive bodies operating at the scale at which provision and trade-offs amongst key ecosystem services (provisioning, regulating, supporting and cultural) can be managed.

b) Inter-ministerial mechanisms at national level to bring together ministries of agriculture, health, gender, environment and education, with mechanisms to include diverse stakeholders, including the rural poor, women, young people and other relevant stakeholders in planning and implementing measures to build SFS for FSN.

c) Development of national FSN policies to set long term goals at national and regional levels, fostering democratic, grass-roots consultative processes including involvement of scientists, indigenous groups, farmer cooperatives, and other stakeholders.

7. DEVELOPMENT AND STRENGTHENING OF LINKAGES BETWEEN URBAN COMMUNITIES AND FOOD PRODUCTION SYSTEMS

States and local authorities should:

a) Support greater food justice and food sovereignty for the urban poor, including consumer cooperatives and multi-stakeholder platforms focused on local and regional markets.

8. REORIENT THE INTERNATIONAL GOVERNANCE SYSTEM, TOWARDS SUSTAINABLE FOOD SYSTEMS FOR FSN

States and intergovernmental organizations should:

a) Develop and apply at an international level, a broader set of metrics to assess SFSs, including nutritional yield, ecological footprints, equity, access, agency and other multidimensional performance measures of agricultural production and food value chains.

b) Reorient global governance systems such as the World Trade Organization and the International Monetary Fund to allow more democratic grassroots civil society input into policies, to strengthen SFSs for FSN.

c) Encourage UN agencies such as IFAD, UNEP, WHO and FAO to adopt an SFS for FSN approach in their programmes and increase collaboration in this area.

9. ADDRESS SOCIAL INEQUALITIES ESPECIALLY IN RESPECT OF GENDER AND YOUNG PEOPLE, UNDERLINING NUTRITIONAL ASPECTS OF FOOD SYSTEMS

States and intergovernmental organisations should, in addition to the measures specifically mentioning gender and young people already integrated into recommendations 1-8**:**

a) Undertake a holistic assessment of the issue of employment in agriculture; appreciating that many “alternative” systems have greater labor needs but also greater capacity to create to “contributive justice”- promotes work that develops people’s capabilities and their potential, and is done under fair conditions.

b) Develop interventions that provide strategies and tools to deliver nutrition sensitive agriculture, including homestead food production systems, aquaculture, dairy, small livestock rearing, crop diversity and value chains for nutritious foods

c) Support farmer-led food sovereignty and agro-ecological approaches that advocate for women's formal rights to land access, and more equitable family and community relationships

d) Reorient institutions and organizations to explicitly address gender inequalities, including girls' access to education

e) Recognize the particular constraints and challenges that young people face in trying to establish diversified farming systems, such as their access to land.

f) Recognize that a key mediator of food security and nutrition is through gender equity in access and control over resources and assets, women's allocation of food, health and care, time use and women's own health and nutritional status.

INTRODUCTION

The UN Committee on World Food Security (CFS) has tasked its High Level Panel of Experts on Food Security and Nutrition to produce this report on "*Agroecological approaches and other innovations for sustainable agriculture and food systems that enhance food security and nutrition"* recognizing that the global food system is not meeting the needs of the current world population, with around 820 million people hungry (FAO *et al.*, 2018). This will be exacerbated as the world faces mounting challenges of continued population increase, urbanization and climate change into the future. While world food production measured in calories has generally risen faster than population, current food systems result in food and nutritional insecurity in some regions alongside epidemics of obesity in others, while the natural resource base that ultimately sustains productivity in the long run is being severely impacted by climate change, degradation of ecosystem functions and loss of biodiversity. The global food system is at a crossroad, and new directions are needed. There are increasing calls for agroecology, seen as counter to business as usual industrial agriculture, to play a greater role in achieving global food security and nutrition (FSN) (De Schutter, 2010; HLPE 2016, 2017a, 2017b; UNGA, 2013).

There is a search for new agricultural and food system solutions that can address these challenges, this generates debate while the global community struggles to find consensus. More sustainable food systems are needed that ensure sufficient food production while also safeguarding socio-economic standards and environmental protection. Agroecological approaches are becomming increasingly prominent in this debate because they are seen to have such attributes, alongside a number of other approaches to changing food systems. It will be the capacity offered by such approaches to facilitate and sustain change – that is, to generate innovation that will determine the extent of their success in making effective transformations of the global food system.

In commissioning this report, CFS takes as the key metric within this report, "the potential contribution of agroecological and other innovative approaches, practices and technologies to creating sustainable food systems that contribute to food security and nutrition".[1] Recognising the current dialogue around the scope of both sustainable food systems and food security and nutrition, the HLPE has incorporated concepts and aspects of both of these that build on previous HLPE publications but extend the scope to better address sustainability of food systems and their nutritional outcomes.

Sustainable Food Systems

The HLPE (2014) has defined sustainable food systems (SFS) 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."*

Three interwoven operational principles for sustainable agriculture development, that could be applied more broadly not only to agriculture but to whole food systems to design pathways towards sustainable development and enhanced FSN were proposed by HLPE (2016): (i) **improve resource efficiency**, (ii) **strengthen resilience**, (iii) **secure social equity** / **responsibility**, which address rational use of inputs and scarce resources, contending with climate change, and bringing social dimensions more centrally into food systems. Agroecology and related approaches such as agroforestry, permaculture and organic agriculture bring attention to an important fourth aspect, fundamental to their innovative nature: the application of ecological concepts and principles to the design and management of sustainable food systems, harnessing natural processes, and creating beneficial biological interactions and synergies among the components of agroecosystems. To capture these important processes that are the cornerstone of approaches and innovations explored in this report, a fourth operational principal for sustainable development is proposed, to (iv) **enhance ecological footprint**. While minimizing environmental impacts have sometimes been included as part of improving resource efficiency, in the context of agroecology with a large focus on ecological processes, it is important to expand the operational principles to include a dimension that sufficiently addresses broader environmental externalities, both positive and negative of agriculture and food systems, by including the ecological footprint.

Food Security and Nutrition

"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"

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

(FAO, 1996). Conceptually, food security and nutrition overlap, with food security a necessary but not sufficient condition for nutrition security (Jones *et al.*, 2015). This HLPE report examines the evidence for different approaches on both food security and nutrition. FAO defines nutrition security as: "a situation that exists when secure access to an appropriately nutritious diet is coupled with a sanitary environment, adequate health services and care, in order to ensure a healthy and active life for all household members." The four pillars of food security, as embraced by several international organizations include the following (FAO, 2006):

1. **Availability:** availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports.
2. **Access:** access by individuals to adequate resources (entitlements[2]) for acquiring appropriate foods for a nutritious diet. This dimension includes physical access to food (proximity) and economical access (affordability) (HLPE, 2017).
3. **Utilization:** 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. This dimension highlights the importance of non-food inputs in FSN.
4. **Stability:** to be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to adequate food as a consequence of natural, financial, or social shocks as well as seasonal variability. Stability therefore refers both to availability and access, but also to stability of the abovementioned non-food inputs.

The discourse on empowerment associated with access to food (that encompasses agriculture and natural resource management, 'access' has two critical dimensions, asset-based agency, which is what is currently emphasised under access as the second FSN pillar above, and institution-based opportunity structures (or agency), essentially concerned with where powers reside, and their transfer where necessary to effect empowerment (Sen, 1982, Chomba *et al.,* 2016), that is central in debates around the democratisation of food systems.

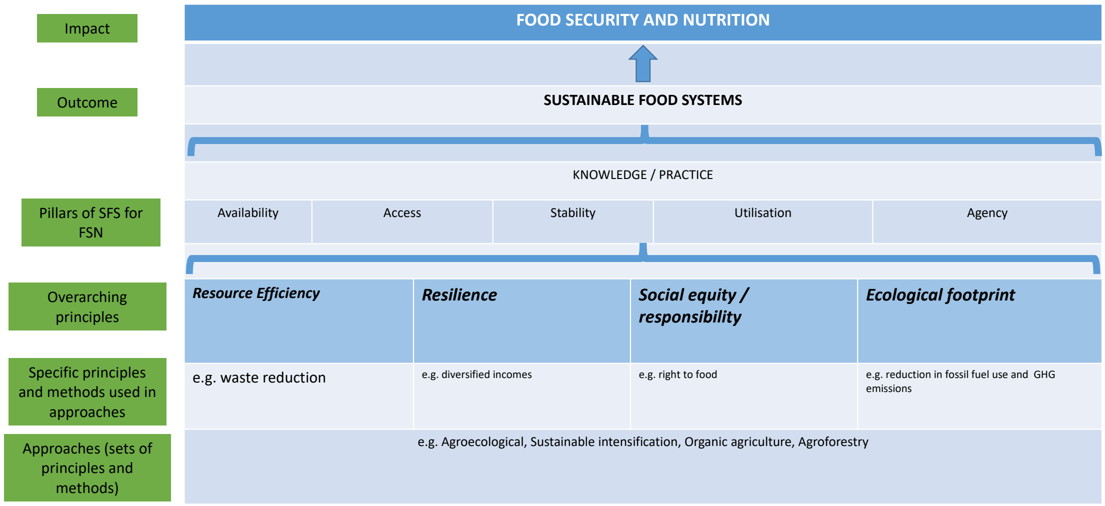
Increasing evidence since the four pillars were first articulated indicate a need for more explicit ways of addressing critical aspects of human empowerment, recognition of rights and reinforcement of community capacities (in particular with respect to water and sanitation, infant and young child nutrition, and the education of women) to make progress in achieving FSN outcomes (Smith and Haddad 2015). Respecting this discourse and the evolving understanding of what is needed to make enduring impacts on food insecurity and insufficient nutrition, the framework for working towards FSN used in this report incorporates a fifth pillar on 'agency' in keeping with its emergence as a critical dimension of FSN (Rocha 2009, Chappell 2018):

5. **Agency:** empowerment of citizens in defining and securing their own food and nutritional security, requiring 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. This includes access to accurate information, the right to such information and to other aspects of food security, and the ability to secure such rights.

Figure 1 suggests a conceptual framework for addressing FSN that relates approaches to outcomes and impact via the application of specific principles associated with approaches that contribute to the generic operational principles underpinning the five pillars.

[2] 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)

Figure 1 Approaches seeking to create sustainable food systems that contribute to food security and nutrition



Definition 1 Approach to FSN

We define an approach to FSN as a set of principles, practices and methods that is widely understood, promoted and practiced with the intention of enhancing FSN.

There is no single approach that embraces the entire agriculture and food system from production to consumption and there is a lot of overlap as well as distinctions amongst the approaches that do exist. This report focuses on prominent approaches currently being applied to FSN and how they use and apply innovation and innovation systems, with varying degrees of success, in developing SFSs that contribute to FSN. This embraces innovations and approaches to innovation other than those within the agroecological domain. The report examines the current discourse on innovation and innovation systems, of relevance to the current challenges of SFSs for FSN.

Structure of the report

This report comprises four chapters. The first deals with what an agroecological approach to FSN comprises, charting the emergence of agroecology as a science, a set of practices and a social movement. The second deals with the nature of innovation systems appropriate for addressing FSN exploring and comparing nine prominent approaches. These approaches and the innovation systems associated with them are each embedded in particular world views and value systems, and often these views diverge. Key divergent narratives and areas of controversy arising in the discourse over different pathways toward SFSs are identified and presented in Chapter 3. The intention is not to resolve such controversies, but to clarify their nature and present the areas where different views and values bring different perspectives to a common issue. Chapter 4 concludes, on the basis of the approaches presented and the divergent narratives explored, to address the drivers, barriers and enabling conditions for innovative approaches to contribute to the radical transformation of current food systems needed to enhance FSN and sustainability.

1 AN AGROECOLOGICAL APPROACH TO FOOD SECURITY AND NUTRITION

Agroecology is a dynamic concept that has gained prominence in scientific, agricultural and political discourse in recent years (IAASTD, 2009; IPES-Food, 2016), with the United Nations (UN) Special Rapporteur on the right to food highlighting agroecology as a viable approach to progress towards FSN (De Schutter, 2010). 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, 2015b; FAO, 2016), a further three regional meetings in 2016 in Latin America, China and Europe, and the most recent in 2017 in North Africa (FAO, 2018a). A second International Symposium was convened by FAO in April 2018, key outcomes of which are documented in Chapter 4 and have informed the development 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 science, a set of practices, as well as a social movement. An overview of each of these dimensions with examples and definitions is provided.

In the second part of the chapter, the progressive definition and development of agroecological principles is presented alongside how they have been broadened in recent years to include new dimensions. These principles are summarized for this report and also analyzed in relation to their scale of application, how they contribute directly or indirectly to FSN and how agroecology contributes to achievement of the Sustainable Development Goals (SDGs).

The third part of this chapter outlines contested areas in current debates within agroecology which stem from varying perspectives, focus, proponents and goals. Major knowledge gaps are also highlighted. Finally, this section defines agroecological approaches to FSN for the purpose of this report.

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

There is a proliferation of definitions of agroecology as different institutions and countries provide definitions for agroecology that reflect their concerns and priorities (**Box 1**). The HLPE has described agroecology in relation to FSN, 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 (HLPE, 2016). This conflates agroecology itself with an agroecological approach to FSN, focusses on farming rather than whole food systems and attempts to separate scientific and technical dimensions of agroecology from the social and political dimensions, rather than embracing a transdisciplinary outlook. For this report there is a need to define and characterise agroecological approaches for sustainable agriculture and food systems that enhance FSN. This involves distinguishing agroecology *per se* from an agroecological approach to FSN, applying the concept to whole agri-food systems (Thompson and Scoones, 2009) and recognising that the transdisciplinary nature of an agroecological approach embraces **science**, a **set of practices** and a **social movement** (Wezel *et al.,* 2009;. Wezel and Silva, 2017, Agroecology Europe 2017).

As outlined in the introduction, agroecology is the application of ecological principles in agriculture. This is a complex concept because ecology refers to both the branch of biology dealing with interactions amongst organisms and with their environment (Tansley, 1935) and a political movement concerned with protection of the environment (Sills, 1974), while agriculture is the set of practices through which people produce food[3] (Spedding, 1996). Although ecological science began as a sub-division within 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, as a concept is also evolving, with an increasing realisation that it is often not useful to separate production of food, from other aspects of whole food systems that embrace the production and consumption of food and all that is involved between these along food chains (Jones and Street, 1990). These trends in ecology and agriculture come together in an emerging transdisciplinary focus on understanding and managing coupled social-ecological systems (Berkes and Folk, 1998) that are gaining increasing prominence as concerns mount about human activity and agriculture in particular, leading to planetary boundaries being exceeded (Steffen *et al.*, 2015). 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 development of resilient food systems in the face of climate and other global change (Caron, 2014).

Box 1 Proliferation of definitions of agroecology

Agroecology emphasizes the importance of collaborative, transdisciplinary and participatory approaches across agricultural, food, nutritional and social sciences.

As a science, commonly used definitions are: (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, Dalgaard *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).

As a set of agricultural practices, agroecology seeks ways to improve agricultural systems by harnessing natural processes, creating beneficial biological interactions and synergies among the components of agroecosystems (Gliessman, 1990) and using in the best way ecological processes and ecosystem services for the development and implementation of practices (Wezel *et al.,* 2014). Moreover, agroecology is also seen as a transdisciplinary, participatory, and action-oriented approach (Méndez *et al.,* 2013; Gliessman, 2018).

As a social movement, agroecology is seen as a solution to current challenges such as climate change and malnutrition, contrasting with the predominant 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, fair and safe food production. It defends 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 important (Gonzalez de Molina, 2013; Toledo and Barrera-Bassols, 2017).

Source: (FAO, 2017) Agroecology Europe (2017).

[3] Spedding (1996) defines agriculture as a human activity carried out primarily to produce food and fibre (and fuel, as well as many other materials) by the deliberate and controlled use of (mainly terrestrial) plants and animals.

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 2b**) (Bensin, 1928, 1930; Friederichs, 1930; Klages, 1942; Gliessman, 1997; 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 with the title "Agroecology" (Tischler, 1965).

The concept of "agroecosystem", considered as a domesticated, human-managed ecosystem, was introduced by Odum (1969). At this time, 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).

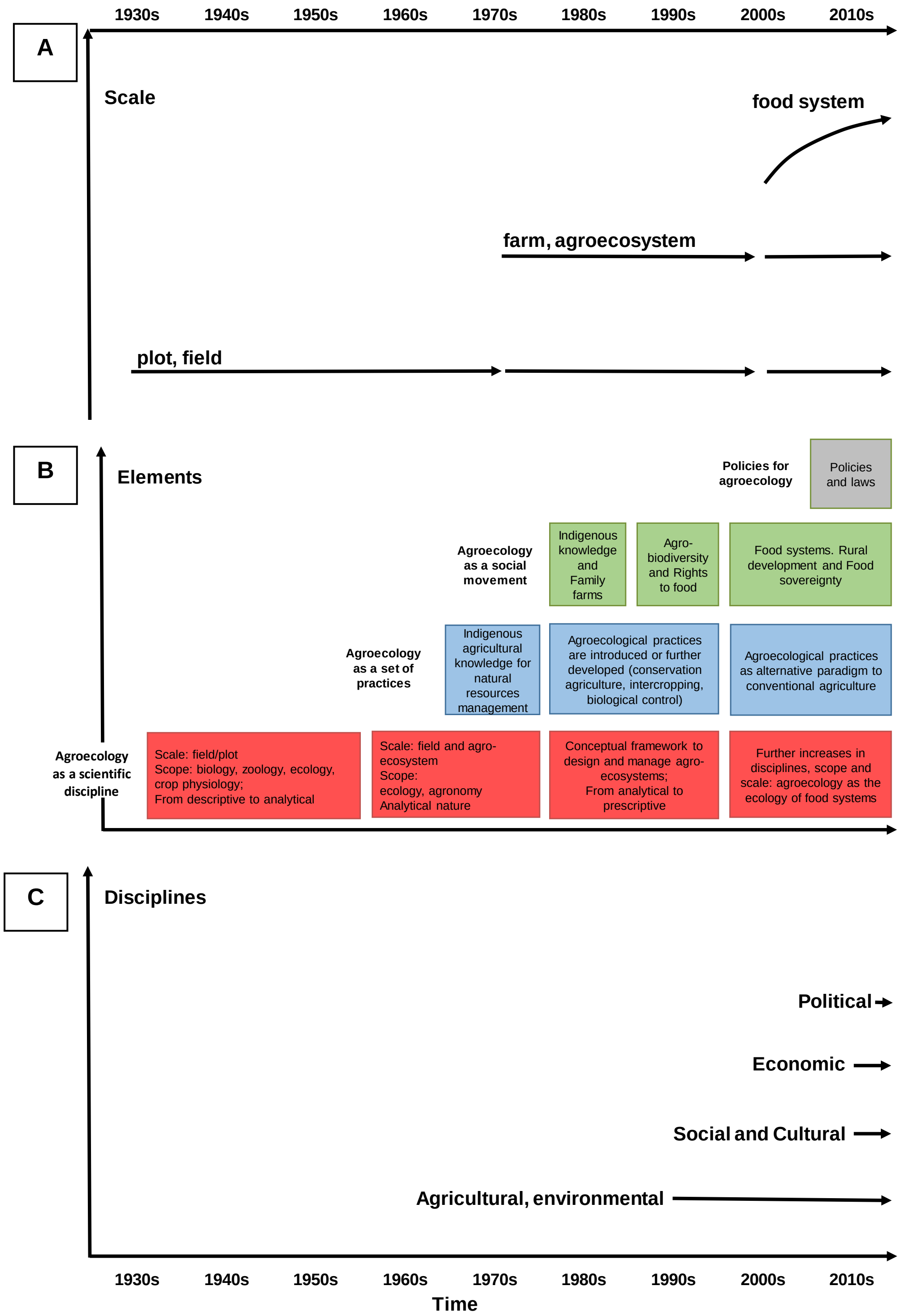
Building on these reflections, Altieri (1995) defined agroecology as *"the application of ecological concepts and principles to the design and management of sustainable agroecosystems".*

A few years later, the focus of agroecology was further broadened and the food systems dimension began to be included in definitions and applications (Francis *et al.,* 2003; Gliessman, 2007; Wezel and David, 2012) as also reflected by FAO (COAG/2016/6) in 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".* The realization that a combination of different scientific disciplines needed to be integrated in agroecology led to it being described as *"an integrated discipline that includes elements from agronomy, ecology, sociology and economics"* (Dalgaard *et al.,* 2003), and the interdisciplinary nature of the approach, combining natural and social sciences has since become increasingly important (Wezel *et al.,* 2015). The food systems' approach also includes the relationship and linkages between rural and urban areas, and more recently has led to the development of urban agroecology (Morales *et al.* 2018).

Agroecological approaches embrace the local knowledge of food producers (farmers, pastoralists, fisherfolk, forest dwellers and indigenous peoples) as providing useful insights to improve food systems (Vanloqueren and Baret, 2009; Cerdan *et al.,* 2012). The challenge is to combine the latest insights from science with the local knowledge and practical experience of small food producers through transdisciplinary, participatory and action-oriented approaches (Stilgoe *et al.,* 2013; Pimbert, 2015; Méndez *et al.,* 2013, 2015). In Latin America, the *"Campesino a Campesino"* movement, encouraging a horizontal process of generation and exchange of knowledge, ideas and innovations, among farmers, played a central role in the scaling-up of agroecology (Holt-Gimenez, 2006; Altieri *et al.,* 2012).

In the historical evolution of agroecology as a science (**Figure 2a**), 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 the ultimate focus for agroecology (Wezel and Soldat, 2009).

Figure 2 Historical evolution of agroecology



Sources: (a) scales (adapted from Wezel *et al.*, 2009), (b) elements, showing the emergence of the three major facets of agroecology (science, practice and social movement) with key topics and the nature and scope of research (adapted from Silici, 2014, based on Wezel *et al.*, 2009 and Wezel and Soldat, 2009), and (c) disciplinary basis of principles articulated within agroecology `(see 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 chemical inputs in agriculture on the environment, particularly the concentration of pesticide residues through food chains impacting birds of prey. Partly in response to this a set of agroecological practices emerged (**Figure 2b**) aiming at moving away from what has been called an "industrial agriculture model", dominated by large-scale specialized farms, relying heavily on fossil fuel and external chemical inputs, towards more environmentally-friendly and sustainable agricultural systems, optimizing the use of biological processes and ecosystem functions (Rosset and Altieri, 1997; Wezel *et al.,* 2009; Vanloqueren and Baret, 2009; Altieri *et al.,* 2012; Wibbelmann *et al.,* 2013; Pimbert, 2015; IPES-Food, 2016; FAO, 2016b; Wezel *et al.,* 2014; Wezel, 2017). This was summarised by Altieri, 2002 as designing complex and resilient agroecosystems that, by *"assembling crops, animals, trees*, *soils and other factors in spatially and temporally diversified schemes, favor natural processes and biological interactions that optimize synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity"*.

Although the term "agroecological practices", attempts to define which specific practices qualify as agroecological, are only recently emerging: "agricultural practices aiming to produce significant amounts of food while valuing ecologicalprocesses and ecosystem services by integrating them as fundamental elements" (Wezel *et al.,* 2014). But there is no definitive set of practices proscribed as agroecological (Wezel, 2017). It might be easier to discuss practices as being more or less agroecological, depending on the extent to which: (i) they make use of ecological processes as opposed to external inputs, (ii) they are are equitable, environmentally friendly and locally adapted and owned.

Agroecological practices try to harness, maintain and enhance biological and ecological processes in agricultural production, in order to reduce the use of external inputs (including fossil fuel and agrochemicals) and to create more stable, resilient and productive agroecosystems including developing appropriate responses to new pest epidemics such as the recent spread of fall armyworm in Africa (see **Box 2**). They involve processes that decrease the use of external inputs and enhance ecological footprint, such as nutrient cycling, biological nitrogen fixation, natural regulation of pests and diseases, soil and water conservation, biodiversity conservation, and carbon sequestration, and in so doing contribute to improving the sustainability of agroecosystems. Agroecological farming emphasizes diversification, mixed cultivation, intercropping, cultivar mixtures, habitat management techniques for crop auxiliaries, biological pest control, improvement of soil structure and health, biological nitrogen fixation, recycling of nutrients, energy and "waste'" as inputs to the production process, as with use of manure and compost (Reijntjes *et al.,* 1992; Altieri 1995; Nicholls *et al.,* 2016; Wezel *et al.,* 2014; Wezel, 2017).

Some of these practices have already been applied to varying extents in different parts of the world for decades, while others have been more recently developed with as yet a limited level of adoption (Wezel *et al.,* 2014; Wezel and Silva, 2017). For example, organic fertilisation, split fertilisation, reduced tillage, drip irrigation, biological pest control, and cultivar choice are already widely integrated into temperate agriculture, while biofertilizers, natural pesticides, crop choice and 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 and farm and landscape scales while prevalent in some tropical contexts are less evident in temperate agriculture.

Box 2 Agroecological approaches and practices to control Fall armyworm in Africa

Fall armyworm (FAW), a voracious agricultural pest native from North and South America, was first detected on the African continent in 2016 (Goergen *et al.*, 2016). Since then it has spread to virtually every corner of sub-Saharan Africa affecting thousands of hectares of crop land. It has been predicted that FAW could cause up to $US13 billion per annum in crop losses across sub-Saharan Africa (Abrahams *et al.*, 2017), thereby threatening the livelihoods of millions of poor African farmers. In their haste to respond to FAW, governments have sometimes promoted indiscriminate use of chemical pesticides which, aside from human health and environmental risks, are likely to undermine pest management strategies that depend to a large degree on natural enemies (Abate *et al.*, 2000; van Huis and Meerman, 1997; Wyckhuys and O'Neil, 2010). Subsidizing pesticides can create a dependency that neither governments nor smallholder farmers can afford in the long term (Hruska and Gladstone, 1988).

Agroecological approaches (**Figure 3**) offer culturally appropriate low-cost pest control strategies that can be readily integrated into existing efforts to improve farmer incomes and resilience through sustainable intensification and climate smart agriculture. Such approaches include (i) sustainable soil and land management, which improves crop health and resilience to pest attack (Altieri and Nicholls, 2003); (ii) inter-cropping, which can

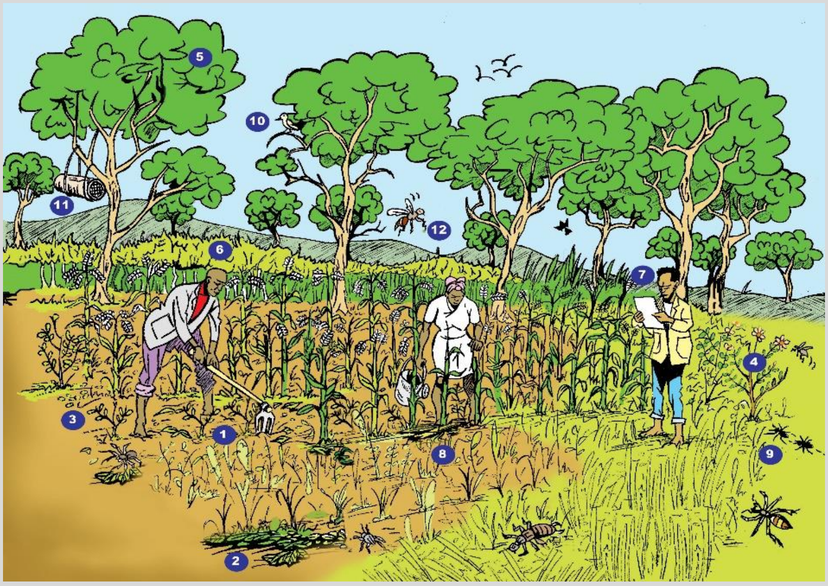
(a) reduce egg laying by pests through volatile chemical deterence (Midega *et al.*, 2018),

(b) increase pest mortality when dispersing among plants (van Huis, 1981), and

(c) provide habitat for natural enemies within the field environment (Rivers *et al.*, 2016); and

(iii) diversifying the farm environment through crop rotation, agroforestry, and management of (semi-) natural habitats at multiple spatial scales, which provides habitat for a variety of natural enemies (Maas *et al.*, 2013; Meagher *et al.*, 2016; Wyckhuys and O'Neil, 2007). Agroecological approaches 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 (Thierfelder *et al.*, 2018).

Figure 3 Examples of agro-ecological approaches to pest management



(1) minimum soil disturbance enhances biological properties of soil, and (2) mulching of crop residues protects the soil surface and adds carbon - both improving soil fertility and crop resilience to pest attack, mulch also provides habitat for insect predators of FAW especially spiders, earwigs, beetles and ants (Clark, 1993; Rivers et al., 2016); (3) planting leguminous inter-crops or cover crops improves soil fertility management through nitrogen fixation, diversifies the field environment for beneficial insects, including insect predators and parasitoids, and through the production of olfactory cues can deter pests from laying eggs (Midega et al., 2018), also in the case of FAW intercrops may trap the ballooning first instar larvae, increasing their mortality (van Huis, 1981); (4) shrubs / trees with flowers or extra flora nectaries support populations of ants and small wasps (Bàrberi et al., 2010; Sisay et al., 2018); (5) boundary trees (e.g. fodder trees, fuelwood trees, shelter trees) provide perches and roosts for birds and bats that predate FAW and increase the structural diversity of the farm habitat through shade and shelter (Maas et al., 2016; Morris et al., 2015); (6) crop rotation – improves soil fertility management and

diversifies the farm environment (Meagher et al., 2016; Rivers et al., 2016; Wyckhuys and O'Neil, 2007); (7) regular scouting by the farmer to identify pests and assess damage enables informed pest management decisions (McGrath et al., 2018); (8) weeds allowed to grow between the maize rows and along field margin can provide habitat for insect predators of FAW and encourage parasitoids and predatory wasps through provision of nectar, however, weeds can also compete with the crop and sometimes provide alternative hosts for pests including FAW, hence detailed understanding of their effects is required (van Huis, 1981); (9) diverse field margins provide habitat for generalist predators, such as spiders, beetles, earwigs and ants (Bàrberi et al., 2010); (10) insectivorous birds and bats provide an important role in reducing pest abundance in diverse agro-ecological systems (Maas et al., 2016); (11) nest site provision for predatory wasps or ants could be used to enhance the local abundance of insect predators (Morris et al., 2015; Offenberg, 2015); (12) predatory wasp – these wasps hunt pest caterpillars (Sousa et al., 2011)

1.1.3 Agroecology as a social movement:

Agroecology has become the political umbrella under which many social movements and peasant organizations around the world defend their collective rights and advocate for a diversity of agriculture and food systems practised by small-scale food producers in different places (Anderson *et al.,* 2015, Nyéléni, 2015). These social movements advocate for a strong connection to be made between agroecology, the right to food and food sovereignty. In February 2015, eight years after a first International Forum for Food Sovereignty (Nyéléni, 2007), diverse social movements and organizations, representing small-scale food producers claiming to produce together some 70 percent of the food consumed globally, gathered in Nyéléni, Mali, 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"* Agroecological approaches often arise in response to agrarian crises, and in concert with broader efforts of social movements to initiate wide-spread change (Mier y Terán Giménez Cacho *et al.*, 2018; **Box 3**).

Box 3 Rede Ecovida in Southern Brazil[4]

The *Rede Ecovida* or 'Ecolife Network' is a decentralized system of cooperatives, farmer groups and non-profit organizations who practice agroecology in 150 municipalities in three southern states in Brazil. The network developed in the 1970s as part of broader social movements mobilizing around issues of environmental damage from agriculture, alongside high levels of social inequality and uneven distribution of land ownership. *Ecovida* currently is made up of 29 farmers' organizations, 2700 farming households, 10 cooperatives, 25 associations, 180 farmers' markets and 30 agro-industries. These groups promote a solidarity economy between producers and consumers in local markets, which go beyond profit. These markets include door-to-door sales, community canteens, farmers markets and restaurants that stretch amongst three states in Brazil. The network uses participatory certification, which ensures that farmers develop relationships with one another and with urban consumers to ensure their practices are rooted in agroecology. In this way the network promotes principles of horizontality, solidarity, justice and care for nature.

Source: Mier y Terán Giménez Cacho *et al.*, 2018

Traditional agricultural systems, in their diversity, are the results 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, therefore, at the heart of agroecology (Altieri, 2004; Wibbelmann *et al.,* 2013; Ploeg and Ventura, 2014).

In order to protect, promote and raise awareness on these traditional agroecosystems, in 2002 FAO started the initiative for the conservation of *Globally Important Agricultural Heritage Systems* (GIAHS) (FAO, 2002; Koohafkan and Altieri, 2010; Koohafkan and Cruz, 2011; FAO, 2016c; HLPE, 2017b). GIAHS are outstanding landscapes of aesthetic beauty that combine agricultural biodiversity, resilient ecosystems, local communities and a valuable cultural heritage. Located in specific sites around the

[4] See also: https://www.ecovida.org.br

world, they sustainably provide multiple goods and services, food and livelihood security for millions of small-scale farmers. These agricultural systems are threatened by many factors including climate change and increased competition for natural resources. They are also subject to out migration because of low economic viability, resulting in traditional farming practices being abandoned and endemic species and breeds being lost. It is thought that these ancestral agricultural systems could constitute the foundation for contemporary and future agricultural innovations where their cultural, ecological and agricultural diversity is still evident and they can be maintained as unique systems of agriculture. There are 50 GIAHS sites in 20 countries six of which, located in China, Philippines, Tanzania, United Arab Emirates, Iran and Republic of Korea are also UNESCO World Heritage Sites. Some GIAHS sites in China are sustaining themselves through dynamic engagement with new technologies through working with e-business companies like Alibaba to promote their agricultural heritage products.

1.2 Principles of agroecology

During its historical evolution, agroecology has expanded beyond the field, farm and agroecosystem scale to encompass, over the last decade, the whole food system. This is now reflected in the recent articulation of principles of agroecology, and the contribution that agroecology is anticipated to make to the 17 Sustainable Development Goals (SDGs) (UN, 2015). This is developed in the following section that looks at the application of agroecological principles across scales and their contribution to FSN.

1.2.1 Key principles of agroecology

Several different sets of agroecological principles can be found in the scientific literature – Reijntjes *et al.,* (1992), Altieri (1995), Altieri and Nicolls (2005), Stassart *et al.,* (2012), Dumont *et al.,* (2013), Nicholls *et al.,* (2016) – that are summarized in Migliorini and Wezel (2018), and more recently FAO (2018) and CIDSE (2018). Today, agroecology is associated with a set of principles for agricultural and ecological management of agri-food systems as well as some wider ranging socio-economic, cultural and political principles. These latter principles have emerged only recently in the literature, arising from the activity of agroecological social movements (**Figure 2c**).

It is argued by many that so-called “industrial” agroecosystems require systemic change to become sustainable and to address food security and nutrition, and that simply implementing some practices and changing some technology is not sufficient; rather the application of agroecological principles and a redesign of farming systems is required (IPES-Food 2016; Nicholls *et al.,* 2016). These principles refer to the promotion of ecological processes and services including soil, water, air and biodiversity aspects. The different principles include: (i) recycling of biomass; (ii) enhancement of functional biodiversity; (iii) provision of favourable soil conditions for plant growth; (iv) minimization of losses; (v) diversification of species and genetic resources in the agroecosystem; and (vi) enhancement of beneficial biological interactions and synergies. The principles of Nicolls *et al.,* (2016) are based on principles previously articulated by Reijntjes *et al.,* (1992) in relation to low-external-input and sustainable agriculture. For agroecological practices involving animals Dumont *et al.,* (2013) added other more specific animal production principles of: (i) adopting management practices aiming to improve animal health; and (ii) enhancing diversity within animal production systems to strengthen their resilience. Peeters and Wezel (2017) defined agroecological principles specifically for grass-based farming systems. Stassart *et al.,* (2012) and Dumont *et al.,* (2016) added further socio-economic principles for agroecology relating to social equity, democratic governance, creating collective knowledge, financial independence, market access and autonomy, and diversity of knowledge and know-how.

FAO recently listed ten elements as guiding principles for agroecology (FAO, 2018b). In guiding countries to transform their food and agricultural systems, to mainstream sustainable agriculture on a large scale, and to achieve zero hunger and other SDGs, the ten elements of agroecology emanated from FAO’s global and regional dialogues. The ten elements represent a synthesis effort, based upon seminal scientific literature on agroecology (in particular Altieri, 1995, and Gliessman, 2007), complemented by discussions held during FAO multi-stakeholder seminars, civil society values on agroecology, and the review of international and FAO experts. These ten elements are incorporated in the summary list of principles below. FAO states that it is increasingly recognized that agroecology addresses, beyond the design framework for sustainable agroecosystems, the economic and social dimensions of food systems in an indivisible way. It follows from this that agroecological principles are considered as general elements of a sustainable food system.

CIDSE (Coopération Internationale pour le Développement et la Solidarité) (2018) also developed, together with different civil society organizations, a set of principles of agroecology. They grouped the different principles into four categories: environmental, social and cultural, economic, and political. Some of these principles refer to the demand and visions of many civil society organizations and their quest to support smallholder and family farming and sustainable livelihoods in the Global South with fair production and market conditions.

The appearance of these four categories of principles in the literature is shown in **Figure 2c**.

To make sense of the wide range of different publications that articulate an increasing number of principles, they are consolidated around the four overarching principles of sustainable food systems for FSN (**Figure 1**) that were set out in the introduction of this report (see **Box 4**). The consolidation involved reducing the number of principles from the three major sources (Nicholls *et al.,* 2016; FAO, 2018; and CIDSE, 2018) to a minimum, non-repetitive list by combining and reformulating them accordingly. Each principle was then allocated to the overarching pathways towards SFS for FSN principle to which it most clearly contributed, that is either (i) resource efficiency; (ii) environmental footprint; (iii) resilience; or (iv) social equity/responsibility. There were more agroecological principles allocated to resilience and social equity/responsibility than the other two categories, although some have relevance across categories. For example, principles 3 and 6 relate to resource efficiency as well as resilience, and 5 to the environmental footprint as well as resilience.

Box 4 A consolidated set of agroecological principles

Resource efficiency

1. Optimize the use of local renewable resources and close resource cycles of nutrients and biomass.

Environmental footprint

2. Reduce or eliminate the dependency on external inputs.

Resilience

3. Secure and enhance soil health for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.
4. Ensure animal health and welfare.
5. Maintain and enhance diversity of species and genetic resources and maintaining biodiversity in the agroecosystem over time and space at the field, farm and landscape levels.
6. Enhance positive ecological interaction, synergy, integration, and complementarities between the elements of agroecosystems (plants, animals, trees, soil, water).
7. Diversify on-farm incomes by giving small-scale farmers greater financial independence and value addition opportunities and enabling them to respond to demand of consumers.

Social equity/responsibility

8. Enhance co-creation of knowledge inclusive of local, indigenous and traditional knowledge and innovation.
9. Promote horizontal (farmer-to-farmer) sharing of knowledge, skills and innovations, together with equal knowledge exchange between farmers and researchers.
10. Build food systems based on the culture, identity, tradition, social and gender equity, innovation and knowledge of local communities and livelihoods.
11. Develop healthy, diversified, seasonally and culturally appropriate diets.
12. Support fair, dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers.
13. 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.
14. Support fair trade, fair employment, and fair treatment of intellectual property rights.
15. 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.
16. 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.

1.2.2 Application of agroecological principles across scales and their contribution to food security and nutrition

As the scope of agroecology has progressively expanded from the farmer's field to the global food system, it is useful to look at how agroecological principles apply across scales. Whereas principle 3 only applies to the field scale, principles 1, 2, 4 and 5 apply at both the field and farm or agroecosystem scales (**Table 1**). Seven principles apply at both the farm or agroecosystem and the food system scales, and three to the food system scale only.

Table 1 Scale of application of agroecological principles and contribution to food security and nutrition

Principle	Scale application FI = field, FA = farm, agroecosystem, FO = food system	Contribution to food security D = direct, I = indirect, NA = not applicable
1. Optimize the use of local renewable resources and close resource cycles of nutrients and biomass.	FI, FA	I
2. Reduce or eliminate the dependency on external inputs.	FA, FO	D
3. Secure and enhance soil health for improved plant growth, particularly by managing organic matter and by enhancing soil biological activity.	FI	I
4. Ensure animal health and welfare	FI, FA	I
5. Maintain and enhance diversity of species and genetic resources and maintaining biodiversity in the agroecosystem over time and space at the field, farm and landscape levels	FI, FA	I
6. Enhance positive ecological interaction, synergy, integration and complementarities between the elements of agroecosystems (plants, animals, trees, soil, water).	FI, FA	I
7. Diversify on-farm incomes by giving small-scale farmers greater financial independence and value addition opportunities and enabling them to respond to demand of consumers.	FA, FO	D
8. Enhance co-creation of knowledge inclusive of local, indigenous and traditional knowledge and innovation.	FA, FO	I
9. Promote horizontal (farmer-to-farmer) sharing of knowledge, skills, and innovations, together with equal knowledge exchange between farmers and researchers.	FA, FO	I
10. Build food systems based on the culture, identity, tradition, social and gender equity, innovation and knowledge of local communities and livelihoods.	FA, FO	I
11. Develop healthy, diversified, seasonally and culturally appropriate diets.	FA, FO	D
12. Support fair, dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers.	FA, FO	D
13. Increase proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems in to local economies.	FA	D
14. Support fair trade, fair employment and fair treatment of intellectual property rights	FA, FO	I or D
15. Recognize and supporting needs and interests of family farmer, smallholder and peasant food producers as sustainable managers and guardians of natural and genetic resources	FA, FO	I
16. 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	FO	D

A crucial question is how the defined agroecological principles relate to FSN. If they are applied, seven out of the 16 can have a direct contribution to FSN, whereas for nine it is less direct. In the case of principle 2 for example, reducing the dependency on external 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.,* 2014; Hwang *et al.,* 2016). This is a primary motivation for the Zero Budget Natural Farming (ZBNF) agroecological movement in India (**Box 5**).

Box 5 Zero Budget Natural Farming – Scaling out Agroecology in India

Zero Budget Natural Farming (ZBNF), is both a set of farming methods, and a grassroots peasant movement in India. ZNBF began in the southern Indian state of Karnataka, where is it estimated that 100,000 farmer families use the methods, while at the national level, it is estimated that millions of farmers use ZBNF (Khadse *et al.* 2018). In 2015 the Government of Andhra Pradesh announced a policy aimed at reaching 500 000 farmers with ZBNF by 2020. As such ZBNF is a successful example of scaling out agroecology.

Interest in ZBNF methods arose in part from the high rates of farmer debt arising from the cost of fertilizer, seed, mechanized agriculture and irrigation, which has 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* chemicals. ZBNF methods include mulching, intercropping, controlled irrigation, contour bunds, local earthworm species and the use of fermented microbial culture and seed treatment which combines cow dung, sugar, pulse flour, urine and soil. At the local level ZBNF operates mainly through volunteers, who come from farmer organizations, community leaders and the founder of the movement, Subhash Palekar, an agricultural scientist who has written many publications on the methods. At the state level, intensive 5-day training camps are held by Palekar, with support from volunteers and allied organizations. A survey of 97 ZBNF farmers reported increased yield, seed diversity, produce quality, household food autonomy, income, and health, alongside reduced farm expenses and credit needs (Khadse *et al.* 2018).

The successful implementation of agroecological approaches by farmers in India has relied on several key strategies (**Table 2**).

Table 2 Elements of successful strategies for implementing ZBNF in India

Strategic element	ZBNF application
Charismatic leadership	A highly charismatic teacher, Subhash Palekar has played a key role in motivating and promoting ZBNF methods through books, training and other public venues.
Horizontal pedagogical practices	While Palekar teaches in a more vertical manner, most of the teaching is done through farmer-to-farmer exchanges and mentoring.
Favorable public policy	Training is provided at the state level in several Indian states. The state of Andhra Pradesh pledges to support 500,000 farmers get trained in ZBNF by 2020.
Local and favorable markets	At least 8 shops exclusively retail ZBNF produce in cities such as Bangalore and Mysore but marketing remains a challeng.
Social organization	State organized training camps and informal networks support training and ongoing support for ZBNF with links to allied organizations.
Effective farming practices	Farmers report improved yields, food quality, income and reduced farm expenses and credit yields.
Cultural legitimacy	ZBNF framed in socially and culturally significant ways, addressing the credit and debt concerns of farmers, and linking practices to spiritual and socially relevant concepts.

Sources: http://www.fao.org/3/BU710EN/bu710en.pdf; http://www.fao.org/3/a-bl990e.pdf and Khadse *et al.* 2018

Similarly, the impact of FSN applies to diversifying on-farm incomes principle (7). The principle 11 of developing healthy and diversified diets, impacts nutrition also directly, with maintaining and enhancing biodiversity (principle 5) having an indirect effect (Bellon *et al.,* 2016; Demeke *et al.,* 2017; Lachat *et al.,* 2018; Jones *et al.,* 2014; Powell *et al.,* 2015). Enhancing co-creation of knowledge, and building food systems based on the culture, identity, tradition, social and gender equity, innovation and knowledge systesm of local communities can also have positive impacts on FSN (**Box 6**).

Box 6 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 program were 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.* 2008; 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 programs had significant improvements in child growth, food security, maternal dietary diversity and self-reported health (Bezner Kerr *et al.* 2010; Owoputi *et al.* 2018; Nyantakyi-Frimpong *et al.* 2016a). 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.* 2018c; Bezner Kerr *et al.* 2016b; Nyantakyi-Frimpong *et al.* 2016b). In households where spouses began discussing farming practices with each other, there was 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 to share seeds and agroecological knowledge, and reported greater resilience under conditions of poor rainfall due to improved soil quality (Bezner Kerr *et al.* 2018b; 2018c).

Key findings from the case study:

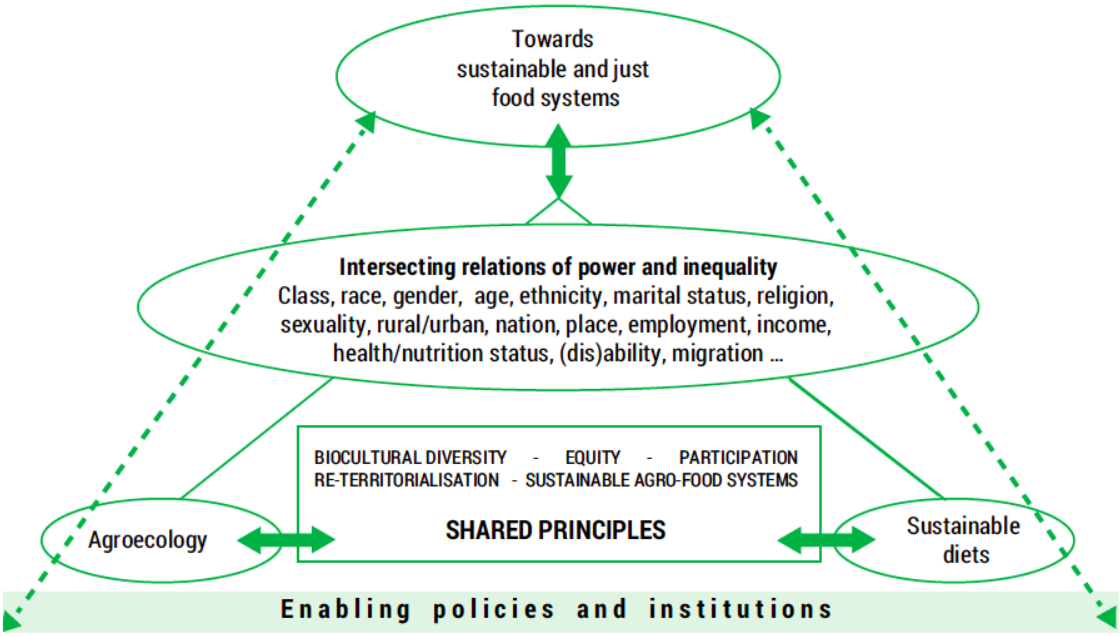
- Farmer-to-farmer teachings and experimentation were the primary teaching approach and were effective at sharing knowledge;
- Unequal social relations including gender inequalities were assessed, discussed and improved over time;
- Relevant educational strategies were developed by local communities to address these inequalities in an iterative way;
- Linking agroecology to food security and nutrition outcomes took at least 2 years before this goal was realized, and required transdisciplinary and participatory approaches.

Source: http://www.fao.org/3/a-br095e.pdf, http://www.fao.org/agroecology/detail/en/c/461072/

A direct link to FSN is also clear for principle 12. 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 (13) may contribute to improving local economies. For example, producers can profit from getting a higher share of revenue if less is taken by intermediaries or long supply chain actors for marketing and distribution of produce. Also, local food enterprises and retailers can increase their price margins and get 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 demand 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 16).

The other nine principles are more indirectly linked to FSN. For instance, principles 1 and 3 support optimizing and securing agricultural production and therefore also potentially food security. Recent studies have noted that for agroecology to significantly impact food security and nutrition and generate sustainable diets, power inequalities must be addressed within the food system at multiple scales and in different dimensions (Mier y Teran Gimenez Cacho *et al.* 2018; Pimbert and Lemke 2018, **Figure 4**). Horizontal teaching methods (principle 8 and 9) are ways that agroecology already addresses social inequities; principles 10-16 articulate how other inequities can be addressed within an agroecological approach.

Figure 4 Agroecology and sustainable diets as complementary and intersecting concepts



Source: Pimbert and Lemke 2018 using concepts from Rosset and Altieri, 2017 for agroecology, Burlingame and Dernini 2012 for sustainable diets and Collins, 2000 for intersectionality.

1.2.3 Contribution of agroecology to the Sustainable Development Goals

The 2030 Agenda for Sustainable Development (UN, 2015) defined 17 Sustainable Development Goals (SDGs) that should be reached by 2030. They were defined in 2015 and entered into force in 2016. Agroecology contributes directly to 10 of the 17 SDGs through integrated practices that cut across many areas (FAO, 2018c), addressing 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 realizing the aims of the Paris Climate Agreement, the Convention on Biological Diversity and the United Nations Convention to Combat Desertification (FAO, 2018c).

The pathways through which agroecology can contribute to reach the SDGs are manifold. Agroecology seeks to transform food and agriculture systems, addressing the root causes of problems and providing holistic and long-term solutions (FAO, 2018c) that considers the complexity of farming systems within their socio-environmental contexts (Petersen and Arbenz 2018). Import pathways for this transformation are co-creation of knowledge, sharing and innovation, including the combination of local, traditional and practical knowledge with multi-disciplinary science (FAO, 2018c). Further pathways to scale-up agroecology and thus to contribute to the SDGs are support of agroecology by public policies, strengthening rural institutions, establishment of networks of knowledge exchange, improving access to markets for smallholder and family farmers, and promote diversity in production and practices that also allow to improve the link between production and consumption at local or territorial levels (FAO, 2018c; Petersen and Arbenz, 2018).

1.3 Contested areas and knowledge gaps in agroecology

Debates, controversies and diverging narratives emerge around agroecology. A key area of contestation is whether political and social dimensions of food production should be considered part of agroecology (Méndez *et al.* 2013; Rosset and Altieri, 2017; Sanderson Bellamy and Ioris, 2017; Giraldo and Rosset, 2018). One stream of scholars and social movements argue, in keeping with earlier debates about agricultural technologies, that without recognizing the social and political implications of agroecology, there will be negative social, environmental and food security consequences for marginalized groups (de Molina, 2013). This argument is in line with earlier work on agricultural technology about the significance of the political, social and economic context for addressing FSN (Bezner Kerr, 2012; Gómez *et al.*, 2013; Stone and Glover 2017). Some scholars propose terms such as *political or transformative agroecology* for those approaches which consider political and social factors to address FSN at a broader scale, contrasted to a more technical-focused agroecology at the field scale (Méndez *et al.* 2013; Sanderson Bellamy and Ioris, 2017). Relatedly, several scholars have drawn attention to the context-specific gender and social inequalities which can have differential labor, cost and other economic impacts of agroecological approaches, and in turn can FSN outcomes (Bezner Kerr *et al.*, 2018; Batello *et al.*, 2019). Some scholars note 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).

Another key area of debate and scholarship relates to the role and extent of indigenous and local food producers in scientific knowledge generation and significance of cultural context for shaping this knowledge, including the role of women, elders, ceremonies, community organizations and opportunities for interaction with scientists (Etkin, 2011; Méndez *et al.* 2013; Snapp and Pound, 2017; International Institute for Environment and Development, 2018). Some argue that traditional knowledge is deep, but narrow, while Western scientific knowledge is broad but shallow, and that agroecology involves the co-production of knowledge through the mutual shaping of the different knowledge streams (Vandermeer and Perfecto, 2013). Scholars and indigenous groups also debate the notion that traditional indigenous knowledge is 'new' scientific knowledge and caution about the dangers of such knowledge being taken out of socio-ecological knowledge (Barthel *et al.*, 2013; Massicotte, 2014; International Institute for Environment and Development, 2018).

Agroecological knowledge often arises from the struggles and efforts of marginalized food producers, providing opportunities for new ways of approaching food production that sustain FSN. Debates about the roles of farmers and social movements in agroecological research relate to the potential to 'scale-out' agroecology effectively. 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 producer-led, decentralized, autonomous knowledge generation as important as the specific technical knowledge being studied (Massicotte, 2014).

The extent to which agroecology effectively addresses gender, ethnic minorities and other social inequalities which influence FSN without explicit attempts to do so is also a point of debate (Massicotte, 2014;Bezner Kerr *et al.*, 2018). There are related debates as to how to measure the impact of agroecological approaches. One debate, related to using multi-cropping instead of monocultures, is about the yield gap measurement and whether to measure total crop output versus single crops (Altieri 2000). Another challenge of assessing impact of agroecological practices is that farmers may selectively apply them, making it difficult to isolate what practices are having an effect (Altieri and Toledo 2011).

Further, another question is whether or not agroecology can feed the world, particularly if the urbanization trend is considered (Chen 2007; Satterthwaite *et al.*, 2010). Some authors argue that agroecology is capable to assure sufficient food, others see the need to primarily increase total food production (see more in chapter 3). Some argue that agroecological production requires more labour and it is more adapted to smallholder farms, and in opposite, there is a need of large operating farms to produce food under limitations of work force. Others suggest that agroecology provides dignified, meaningful work for smallholder rural producers, particularly since it encourages experimentation, ongoing learning and sharing with peers (Bezner Kerr *et al.*, 2018). Agroecology encourages greater autonomy**,** a crucial characteristic of meaningful work, by encouraging farmers and farmworkers become skilled workers that are harder to replace. Having higher crop and animal diversity with a wider range of products that can change the producer- retailer relationships; and reducing dependency on external inputs which provides greater freedom in how to spend income (Timmerman and Félix 2015).

Finally, there is a growing debate about similarities, difference and convergence of organic agriculture and agroecology (Migliorini and Wezel 2018). Whereas organic agriculture includes certification, this is not the case for agroecology, although some initiatives of some stakeholder groups and companies are under way. Discussions include also if synthetic pesticides and chemical fertilizers should be excluded from agroecological production, as under organic agriculture, or be acceptable to a certain degree or in defined situations.

There are a number of knowledge gaps in agroecology research, in part due to the severely limited public investment in agroecological research (Miles *et al.*, 2017; Pimbert and Moeller, 2018). Relevant to this report, two key gaps are how to effectively link agroecology to public policies to address FSN, and what are the economic and social impacts of agroecology, for different groups in communities, including labor costs and FSN (Sanderson Bellamy and Ioris, 2017; Bezner Kerr *et al.*, 2018). A third related research gap is whether there is a yield gap between industrial and agroecological systems; although several studies suggest that there are comparable yields, higher yield stability, particular 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). Relatedly, developing standardized methodological methods for assessing agroecological impacts is another gap (Sanderson Bellamy and Ioris, 2017). How to scale out agroecological approaches in ways which foster democratic processes and address the needs of marginalized groups is another gap, with some evidence for context-specific methods being effective at addressing food security, nutrition and sustainable food systems, if political and economic barriers are addressed (IPES, 2016; Mier y Terán Giménez Cacho *et al.* 2018).

Another research gap is related to the resilience of production systems. In the context of climate change, the design of resilient agricultural systems is an imperative to cope with global warming and increased climate variability. Resiliency is particularly important in areas where is most likely to be affected by extreme climate events such as prolonged droughts, floods, heavy winds, etc. (Ching *et al.*, 2011; Koohafkan *et al.*, 2012; Rhodes 2013; Scialabba and Müller-Lindenlauf 2010; Altieri *et al.*, 2015). Some studies indicate that agroecological systems are more adapted to such context, and even can help to mitigate the effects of climate change (Holt-Giménez 2002). However, further research is needed to better understand the processes that support more resilient systems in different contexts.

Efforts to support knowledge exchange and networks may be crucial dimensions in building resilience (Rogé *et al.* 2014; Bezner Kerr *et al.* 2018).

1.4 Definition of an agroecological approach to FSN for the present report

As discussed above, there are an increasing number of definitions for agroecology provided in recent years, that have different nuance depending on the authors, institutions or civil society organizations that provide them. What they have in common is the goal to develop sustainable food systems that can address FSN. 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 FSN is proffered based on the analysis and information presented in this chapter (**Definition 1**).

Definition 2 Agroecological approach to FSN

An agroecological approach to FSN recognizes that agri-food systems are coupled social-ecological systems from 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. Agroecological approaches favour the use of natural processes over external inputs, closed cycles with minimal negative externalities and stress the importance of local knowledge and participatory processes which develop knowledge and practice through experience, as well as more conventional scientific methods, and address social inequalities.

1.5 Summary

This chapter has outlined how agroecology has developed over the last century, from a field level, agronomy and ecology focused science, to a transdisciplinary, participatory science, movement and set of practices with an extensive scientific evidence base on agroecosystem, farm-based environmental impacts, and emerging evidence around the implications for socio-ecological systems and communities at food system scale. Key principles of agroecology are drawn from the literature and consolidated for this report, and it is shown how they have indirect and direct impacts on FSN within a sustainable food system, and operate at a range of scales. Some key contested areas that fuel current debates within agroecology are outlined and knowledge gaps identified. Finally, a definition of what an agroecological approach to FSN constitutes is provided.

2 INNOVATION FOR SUSTAINABLE FOOD SYSTEMS

This chapter discusses the nature of innovation systems associated with different approaches to sustainable agriculture transitions, with an emphasis on the social process of innovation and on the livelihood benefits derived. Salient characteristics of successful innovation processes in this context are identified. Using these characteristics as criteria, nine prominent approaches to innovation around SFSs are compared. A conceptual framework is presented showing how different innovation approaches use their specific principles to contribute to both the operational principles of sustainable agriculture and food systems, and to the dimensions of food security. Reducing food loss and waste, which is a critical cross-cutting issue for FSN amongst these approaches, is discussed and then each approache (Rights based approaches, Sustainable Intensification, Organic Agriculture, Agroforestry, Climate Smart Agriculture, Permaculture, Nutrition sensitive agriculture, and Sustainable food value chains) are considered in turn, exploring their principles, their origins and manifestations, and their differential contributions to food security and nutrition, as documented in the existing evidence base.

2.1 Innovation theory and practice

Innovation was first defined by Schumpeter (1939) as any way of *"doing things differently"*. This early definition, addressed to the economic community, recognized not only technological changes, but also improvements in infrastructures and markets, as well as organizational changes. Elaborations of different types of innovation have often focused on applications in economic contexts, or from the perspective of a firm; for example, the Organisation for Economic Cooperation and Development (OECD) and Eurostat (2005) distinguished four broad types of innovations: on product, on process, on marketing method and on organization. Typologies of innovation have most often been defined for the measurement of scientific and technological activities in the manufacturing and service industries, of limited relevance for FSN. Similarly, innovation system theory had originally been developed focusing on the flow of technology and related information, among people, enterprises and institutions including universities and research bodies, thus most relevant to technological and industrial contexts (Nelson 1993; OECD 2001; Patel & Pavitt 1994).

In the present discussion of innovation theory and practice, this report recognizes that the concept of innovation derives its meaning within the framework specific contexts and needs. Agricultural innovation has been a major engine for transformation of food production and farming over the last century, with many technological innovations in agriculture having generated significant negative externalities (TEEB 2018). It is increasingly recognized that innovation in food and agriculture needs to address major social challenges to ensure a transition to more sustainable food systems that can deliver enhanced FSN. This implies a need to approach agricultural innovation in a new transdisciplinary way. This section examines the current discourse on innovation and innovation systems, of relevance to the current challenges of sustainable food systems for food security and nutrition.

Innovation theorists have clarified that "innovative" is a transient dimension, in that what is called innovative today may be simply a footnote in history tomorrow. Innovation has been clearly distinguished from research and invention by Schumpeter (1939), stating 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 defining innovation as "the dissemination of something new in a given context, not as something new in absolute terms ". Therefore "what is not disseminated and used is not an innovation". More recent definitions have extended this to include "what is used and has resulted in substantial social and or economic benefit to the user" (FAO, 2014). In short, innovation is not just a synonym for something new, but rather a process, product or arrangement that allows for new benefit when it is used.

Some observers of agricultural innovation systems identify the most recent phase in the evolution of how knowledge is put to use in the agriculture sector involving more emphasis on facilitating local innovation (Saravanan and Suchiradipta, 2017). Agricultural innovation systems pay increasingly greater attention to building innovation capacities of stakeholders in a multi-stakeholder process, with a strong focus on innovations emerging from the grassroots (Assefa *et al.,* 2009). These developments are linked to the realization that socio-economic and ecological context of farmers and communities that determine what innovations are appropriate, vary at fine scale (Coe *et al.*, 2016) and a consequent interest in how best to traverse scales to promote horizontal learning amongst farmers.

Promising developments include facilitation of farmer networking (Nelson *et al.*, 2016), use of citizen science, involving recent developments in ICT to collate and share information involving large numbers of participating farmers (van Etten *et al.*, 2016 Dehnen-Schmutz *et al.*, 2016) and a paradigm shift from research 'for' to research 'in' development, where planned comparisons are built into development praxis (Coe *et al.*, 2014). These all involve forms of mutli-stakeholder innovation platforms (Shut et al, 2018) with an increasing interest in how these can operate at multiple scales. For example, aggregation of village-level landcare groups in Kapchorwa in Uganda to create fora at landscape and regional scales capable of leveraging infrastructural change through influencing local and national government and private sector actors (Catacutan et al, 2014).

Bringing these strands together, FAO recently 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" (FAO, 2016b). Innovation systems have been defined 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" (World Bank, 2012). Innovation platforms have been described as "bring[ing] together groups of individuals (who often represent organisations) 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, 2006).

For the purposes of this report, these definitions are adopted with the following modifications.

Definition 3 Innovations in the context of FSN

- **Innovation:** the process by which individuals, communities or organizations generate changes, including the design, production or recycling of goods and services and the relevant institutional relations that are new to their context and promote transformative differences for stakeholders.
- **Innovation systems:** networks of organizations, communities, enterprises and individuals focused on generating changes, in the form of processes, forms of organization, disseminating knowledge or bringing new products into use, together with the institutions and policies that affect their behaviour and performance.
- **Innovation platforms:** initiatives or efforts that bring together diverse stakeholders to create space for learning, action and change.

2.1.1 Typology of innovation

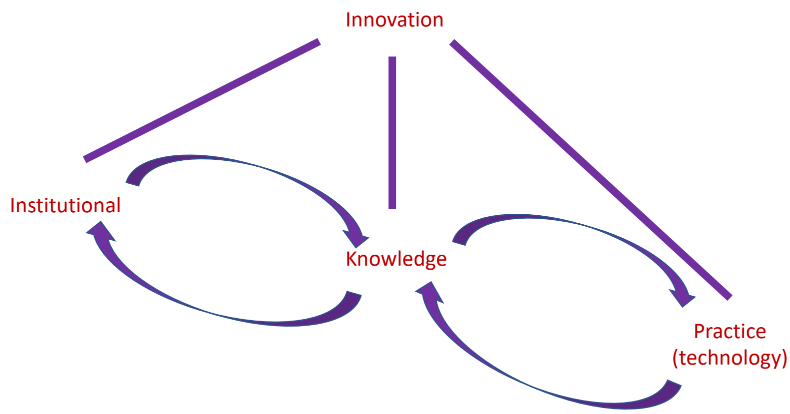
Many reviews of innovation in agriculture refer back to Rogers' "Diffusion of Innovations" (first published in 1962, with a fifth edition from 2003). In this seminal book, Rogers characterized stages of innovation as phases within which individuals participate: from innovators, early adopters, the late majority adopters, and those laggards averse to change (Rogers, 2003). However, 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). Newer conceptualizations of innovation place much more emphasis on social processes of innovation, the fundamental role of local knowledge and adaptation, and the need for change to be built on continuity with the past and to be embedded in local circumstances (Joly 2018; van der Veen, 2010). In a number of respects, a "renewal of innovation" is underway (Joly, 2018), with a discourse that embraces: democratising innovation, promoting ways that communities of people can share information and knowledge across distributed networks (von Hippen 2004), responsible innovation that seeks to steer innovation towards social problems, under inclusive and participatory forms of governance (von Schomberg 2011; Guston 2006), and that invokes moral and collective perspectives and transformative change through the co-production of knowledge (Schot & Steinmueller 2016). All of these aspects of "innovation renewal" have strong linkages to the transformations of food systems, for example participatory plant breeding is noted as an example of democratising innovation (Bonneuil *et al.*, 2006).

From the current discourse, an imperative for assessing successful innovation systems should be not the perceived economic benefit of a new product or practice as calculated in a controlled or research context, but the benefit to the livelihoods and well-being in local situations, as perceived by stakeholders (Kilelu *et al.,* 2012). Agricultural innovations are often proposed to address a need to increase food production. Yet frameworks for FSN (FAO, 2006) recognize that many farmers in resource-constrained conditions, contending with FSN issues, tend to prioritize security stability and flexibility to ensure their ability to feed their families and minimize risk, over increasing output or profit. Similarly, those innovations requiring investments that save labour may not be seen as desirable where labour is more readily available than monetary resources (Dorin, 2017). The social circumstances of farmers play a key role in the decision-making process and therefore on adoption of innovations, as influenced by household structure, land tenure, size of farms, personal wealth and agency (van der Veen, 2010).

Innovations in agriculture are distinct from those in more purely engineering fields, in that ecological relationships and social interactions have a central role. The suitability of an agricultural innovation to local environmental and social conditions is key, and thus local adaptations are integral to the innovation process. Farmers and those working along many food value chains 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).

This leads to a typology of innovation in agriculture that recognises that changes may be principally institutional, relate to knowledge or to practice consistent with the hardware, software and orgware categories of Leeuwis *et al.* (2004) (**Figure 5**) and that these are connected to one another and may be internally generated within an innovation system, be externally introduced to it, or involve both these elements in an adaptive process. Approaches to innovation for FSN, described in greater detail in the following section, have tended to place emphasis on different categories in this typology. For example, sustainable intensification and climate smart agriculture focus on technology, while agroecology, and permaculture stress that innovation is a community-led process based on local knowledge. Rights based approaches focus on institutional innovation.

Figure 5 A typology of agricultural innovation



Source: Adapted from Leeuwis et al. 2004?

2.1.2 Approaches to innovation

Innovation systems are value-laden, emerging within existing social orders, and thus reflecting the predominant 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 being promoted, with approach being broadly 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 practiced with the intention of enhancing FSN”.

The requirements for achieving FSN set out in the introduction to this report encompass the whole food system, from the soil to the organization of human societies. In the rest of this chapter various approaches seeking to generate systemic change toward SFSs that effectively address FSN are described. The agroecological approach to FSN has already been described in Chapter 1. The criteria for selecting the different approaches included here was firstly that they were approaches that explicitly address FSN.

There are many approaches in the literature and practice that purport to address various aspects of FSN (HLPE, 2016), with different approaches tending to emphasize different aspects and a great deal of overlap amongst some of them. To compare these approaches, a list of key aspects that are involved in effectively addressing FSN were identified from the theory of innovation systems set out above and the growing understanding of SFSs that informed the development of the conceptual framework to FSN set out in the introduction to this report.

The 17 key aspects, described in **Box 7**, were used as rows in a comparative table (**Table 3**) of widely promoted approaches to FSN. The table was iteratively refined by combining approaches where completing the table indicated that they were sufficiently similar to one another to be captured in a single column (such as sustainable intensification, ecological intensification and conservation agriculture) or separating them where distinctions emerged, such as climate smart agriculture (CSA), sustainable intensification and organic agriculture, that have sometimes been combined as for example by GACSA (2018)[5] that classify the latter two approaches as forms of CSA. A category of rights-based approaches was included because agency had been identified as an important fifth pillar of FSN in the Introduction to this report that requires emphasis going forward and it was evident that starting from a rights-based perspective was likely to produce quite distinct outcomes from those emerging from the other approaches. The evidence used to complete the cells was based on literature review of each approach fully detailed in Chapter 1 for an agroecological approach and Sections 2.3.1 to 2.3.8 below for the other approaches.

Box 7 Key aspects involved in addressing FSN

Comprehensiveness: Does the approach addresses the whole food system, or only certain parts (such as production, consumption or food waste)?

- **Specific focus on the emerging issue of food waste:** As a deeper focus on the above, and recognizing that this is a relatively new and emerging issue but one with profound implications for food security and nutrition, does the approach encompass a focus on food waste?
- **Specific focus on emerging issue of meat consumption in diets:** Does the approach address a need to reduce meat consumption in diets and cultures where this is an issue?
- **Specific focus on integration:** Does the approach foster greater integration within production/across food chains. Does it have a "systems" focus, with a transdisciplinary lens?
- **Specific focus on markets and supply chains:** Does the approach include a focus on markets and supply chains?

Scale: Does the approach operate at different scales (local, national, global)?

Sustainability: Does the approach address the three dimensions of sustainability (economic, environmental, social)?

Local adaptation: Does the approach respect the need for change to be embedded in local circumstances and developed through local adaptation?

Diversification: As a deeper focus on one aspect of sustainability, gaining increasing attention for profound implications for food security and nutrition, does the approach foster diversity in all respects, - ecological, economic, social?

Degree of adoption and use: Has it been applied and practiced widely?

Social equity and justice: Does the approach address aspects of human rights/right to food, in the context of the social and political circumstances and equity of communities?

Labour: Does the approach have a specific focus on labour?

Knowledge management: Does the approach addresses knowledge management, for example respecting the fundamental role of local knowledge and adaptation or learning as a means of evolving new arrangements specific to local contexts?

[5] http://www.fao.org/gacsa/en/

Technology: Does the approach have a strong focus on technological development (specify in what way)?

Governance: Does the approach addresses issues of governance? Does it promote livelihoods and wellbeing as perceived by stakeholders? Does the approach work to develop capacities for change and innovation that are not merely technical, but are also organizational and institutional?

Circular economies: Does the approach address or contribute to building a circular economy, understood as comprising the formation of networks and links along the supply chain, or between producers and consumers?

Co-existence: For the specific approach, are there issues around co-existence with other approaches?

Table 3 Comparison table between the nine approaches to innovations in sustainable food systems

	Agroecology	Sustainable intensification	Organic Agriculture	Agroforestry	Climate smart agriculture	Permaculture	Nutrition sensitive agriculture	Sustainable food value chains	Rights based approaches
Comprehensiveness	✓	✓▬	✓▬	✓▬	✓▬	✓▬	✓	✓▬	✓
Food waste	✓	✓▬	✓▬	✗	✓▬	✓▬	✗	✓▬	✗
Meat consumption in diets	✗	✗	✓▬	✗	✗	✗	✗	✗	✗
Integration	✓	✗	✓▬	✓	✓▬	✓	✓	✓	✓
Markets and supply chains	✓	✓	✓▬	✓	✓▬	✓▬	✓▬	✓	✓
Scale	⦿	●	⦿	◎	⦿	●	●	⦿	◎
Sustainability	✓	✓	✓	✓	✓	✓	✗	✓	✓
Local adaptations	✓	✓▬	✓	✓	✓▬	✓	✓	✓▬	✓
Diversification	✓	✓	✓	✓	✓	✓	✓	✗	✓
Degree of adoption and use	✓	✓	✓	✓	✓	✓	✗	✗	✓
Aspects of social equity and justice	✓	✗	✗	✓▬	✗	✓	✓	✓▬	✓
Labour	✓	✓▬	✗	✓▬	✗	✓▬	✗	✗	✓
Knowledge management	✓	✓	✓	✓	✓	✓	✗	✓	✓
Technology	✓	✓	✓▬	✓	✓	✓	✓	✓▬	✓
Governance	✗	✗	✗		✗	✓▬	✗	✓	✓
Circular economies	✓	✗	✗	✓▬	✗	✓	✗	✗	✓
Coexistence	✓	✓	✓	✗	✓	✗	✓	✓	✓

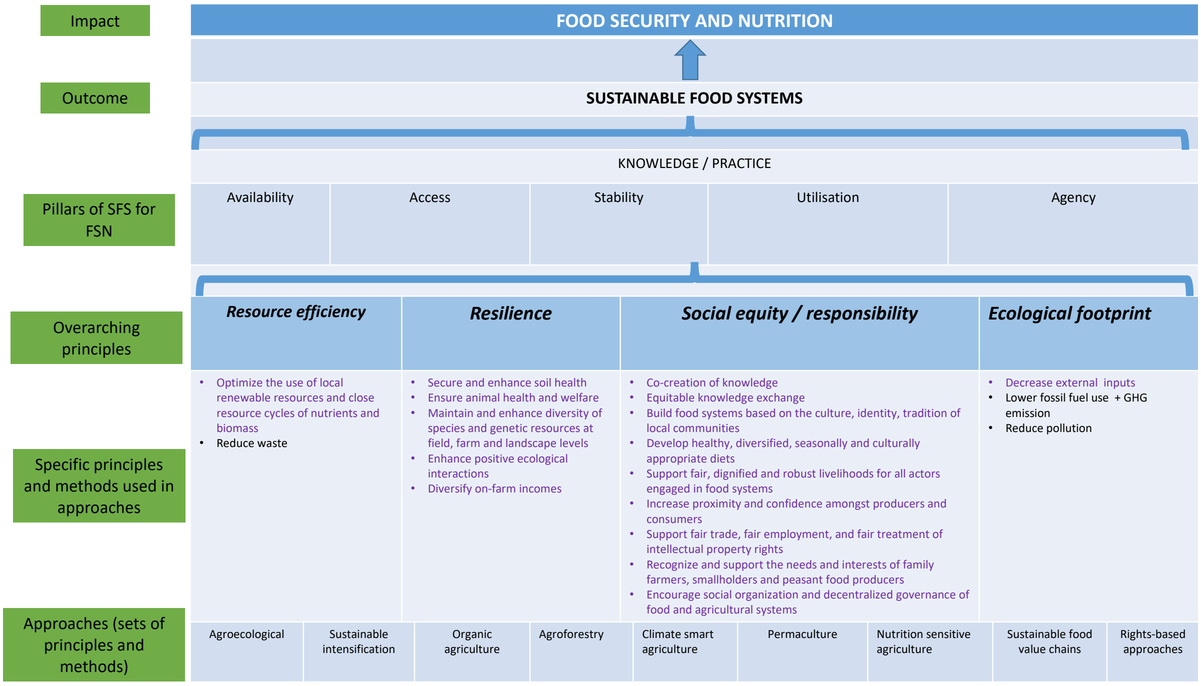
✓ Yes   ✓▬ to some extent/ indirectly   ✗ no   ● local   ⦿ local, national   ◎ global, local, national

2.2 Using the conceptual framework for achieving food security and nutrition to assess innovative approaches

In this report, innovation and innovation systems are viewed as social processes, with fundamental roles for local knowledge and adaptation, recognising the need for change to be a response to context-specific circumstances. The primary focus of this report is to understand in what ways agroecology and other innovative approaches contribute to SFSs for attaining FSN. Agroecology has a distinct and well articulated approach to innovation, encompassing transformations along the entire food system, from the soil to the organization of human societies. Other approaches to transforming agriculture and food systems have different, sometimes unique, and sometimes complementary approaches to generating innovation and change. To understand the strengths and emphases of different approaches and how they impact innovation systems, aspects deemed critical for successful transformations were recognised (as detailed in Section 2.1.2 above) and used to identify nine different approaches. All of these approaches, in partially overlapping but also distinct ways, seek to bring about innovation and change to attain FSN. Most of these approaches distinguish themselves on the basis of their specific set of principles.

The conceptual framework developed for the purposes of this report, relates approaches via their principles, to their impact on SFS for FSN (**Figure 1** in the introduction, expanded here to include specific principles of the approaches in **Figure 6**). The principles have been identified and clustered as they relate to the overarching principles of Sustainable Food Systems: resource efficieny, resilience, social equity and justice, and ecological footprint (**Figure 6**). These in turn contribute to the five pillars of food security (availability, access, stability, utilisation and agency).

Figure 6 Framework showing how innovation approaches contribute to SFS for FSN via their specific principles



2.3 Innovative approaches towards sustainable food systems for FSN

In this section each of the approaches to innovation in relation to developing SFS for FSN identified at the bottom of Figure 6 are characterised. The agroecological approach is already described in detail in Chapter 1. The objective of this section is to assess how these approaches can contribute to FSN and sustainable development. Questions being asked are what are their unique strengths and salient characteristics that might serve as exemplars to other approaches seeking to generate innovations and engage with all dimensions of FSN? It should be noted that no one initiative addresses all aspects, and they are not presented here to suggest that they are competing “brands”; rather that a dialogue amongst them can foster cross-learning to help make approaches more robust and comprehensive. In this sense, we are not providing a hierarchical typology or classification of these approaches, beyond what is evident in **Table 3**. They are heterogenous, addressing different aspects of the food value chain, and incorporate diverse perspectives on how best to do this. In the following sub-sections each is described, elucidating their principles, key points or characteristics, their contributions to food security and nutrition, and how they seek to impact innovation systems. Given the critical cross-cutting importance of reducing food waste and loss, the dimensions of initiatives around this issue are profiled in a following section (2.3.9).

2.3.1 Rights-based approaches, encompassing food sovereignty, women's empowerment and right to food

Brief description of rights-based approaches: Several approaches to addressing FSN can be subsumed under rights-based approaches – addressing political, social, economic and cultural rights – including *food sovereignty, right to food, food justice* and *women's empowerment*.

Food sovereignty

Food sovereignty, which was first launched by social movements led by small-scale producers who make up La Via Campesina[6] (LVC), in 1996 at the United Nations World Food Summit, is a broad concept focused on people's right to control who, how and what kind of food is produced. At the International Forum on Food Sovereignty in 2007, 600 participants from 80 countries developed the most widely accepted definition known as the Nyéléni Declaration:

> *"Food sovereignty is 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. It puts the aspirations and needs of those who produce, distribute and consume food at the heart of food systems and policies rather than the demands of markets and corporations. It defends the interests and inclusion of the next generation. It offers a strategy to resist and dismantle the current corporate trade and food regime, and directions for food, farming, pastoral and fisheries systems determined by local producers and users. Food sovereignty prioritises local and national economies and markets and empowers peasant and family farmer-driven agriculture, artisanal fishing, pastoralist-led grazing, and food production, distribution and consumption based on environmental, social and economic sustainability. Food sovereignty promotes transparent trade that guarantees just incomes to all peoples as well as the rights of consumers to control their food and nutrition. It ensures that the rights to use and manage lands, territories, waters, seeds, livestock and biodiversity are in the hands of those of us who produce food. Food sovereignty implies new social relations free of oppression and inequality between men and women, peoples, racial groups, social and economic classes and generations." (Nyéléni, 2007)*

Food sovereignty arose in response to smallholders' concerns about threats and loss of rights over land, water, seeds and markets, in particular with changing trade regimes, liberalization and increased globalization of agriculture and food (Wittman *et al.,* 2010). Family farms produce the majority of food globally (Graeub *et al.,* 2016). Structural adjustment policies, new multilateral trade agreements such as the North American Free Trade Agreement, and the integration of agriculture into the World Trade Organization, affected smallholders' communities, livelihoods, food security and well-being (Wittman *et al.,* 2010). 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 food (Burity *et al.,* 2010).

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

[6] 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 defense of food sovereignty.

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

Contribution of food sovereignty to FSN: FSN in this approach is ensured through supporting local producers and protecting local markets from ”dumping” of surplus subsidized food from elsewhere (Wittman, 2011). Agrarian reform, which addresses contemporary processes of land concentration as well as historical inequalities in land access, is often a key dimension of ensuring food sovereignty. McMichael (2009) estimates that more than 30 million small-scale producers lost access to land in the decade following the establishment of the World Trade Organization. There are ongoing concerns with land concentration, rising land prices, public incentives for exports by large-scale industrial agriculture and other pressures that push small-scale producers off the land and exacerbate inequalities. Another key dimension of food sovereignty is that of ensuring public access and control over agricultural and food knowledge, in a global context in which intellectual property regimes tend to support commodified intellectual property in the form of patents, copyrights and trademarks (Pimbert, 2018). In contrast, food sovereignty emphasizes the need to recognize, support and protect local and indigenous knowledge of preserving and cultivating seeds, food and livestock, and collecting uncultivated foods. Agroecological production practices are a related aspect of food sovereignty, both as a means for small-scale producers to increase their autonomy over the production process, and as a way to addressing FSN – through small-scale farms that have multifunctional diverse cropping systems that enhance ecological values as well as social and economic rights (Wittman, 2011; Wittman *et al.,* 2017). Gender equity is a key imperative of food sovereignty, in that addressing women’s rights to land, control of resources, and decision-making about food and agriculture is fundamental to addressing unequal power relationships in the food system (Patel, 2012). Addressing gender inequity using a food sovereignty framework can be done at multiple scales, from ensuring land access, to respecting and fostering women’s knowledge of seed varieties, to addressing domestic violence (Patel, 2012).

Innovation and innovation systems for food sovereignty: Food sovereignty approaches encompass a wide range, from small-scale, civil society groups organizing to establish community gardens in low-income neighbourhoods in Canada, to large-scale social movements peacefully occupying unused land in order to ensure poor households can farm in Brazil (Wiebe *et al.,* 2011; Wittman *et al.,* 2010). Public policies that focus on local procurement of sustainably-produced food for school feeding programmes, or that target groups vulnerable to food insecurity, are ways that food sovereignty might be implemented at the state level (Wittman and Blesh, 2017). 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).

<u>CONSEA</u>

Brazil has been internationally recognized for the recent advancements in promoting public policies for addressing food security and nutrition. One of these policies is the National Council for Food and Nutrition Security (CONSEA), an institutional space for social control and participation of society in the formulation, monitoring and evaluation of public policies on food and nutritional security, aiming to promote the Human Right to Adequate Food. CONSEA is part of the National System of Food and Nutrition Security (Sisan) and is composed two-thirds of civil society representatives and one-third of government representatives. The presidency shall be held by a representative of civil society, nominated among its members and appointed by the Presidency of the Republic (Consea, 2017).

<u>Women’s Empowerment</u>

Brief description of women’s empowerment: There is not a single definition of gender inequality or women’s empowerment, but in many instances, 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). 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). Patel (2012) argues that food sovereignty ”invites” a feminist analysis, due to the approach to power relationships embedded in the concept.

Contribution of women’s empowerment to FSN: Gender relationships are intricately linked to FSN outcomes of food systems (Schutter, 2013). Overcoming multiple sources of inequality, including gender inequality, is a rights-based approach to addressing FSN.

Innovation and innovation systems in women's empowerment: 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).

Right to food

Brief description of 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) is a key international covenant that 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).

The process that led to the Voluntary Guidelines for the Progressive Realization of the Right to Adequate Food in the Context of National Food Security (VGRtF), adopted in 2004, was the historical precedent for the inclusive and participatory approach to governance of FSN which was then installed with the Reform of the CFS in 2009. The mandate to contribute to the progressive realization of the Right to Adequate Food was included into the Vision Statement of the reformed CFS and has since been reaffirmed in most substantive CFS policy decisions.

- The CFS Vision Statement of the CFS Reform says: "The CFS strives for a world free from hunger where countries implement the voluntary guidelines for the progressive realization of the right to adequate food in the context of national food security". (CFS:2009/2 Rev. 2).
- All major products of the CFS, the Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security (VGGT), the Global Strategic Framework for Food security and Nutrition (GSF), the Principles for responsible investment in agriculture and food systems (RAI), the Framework for Action for FSN in Protracted Crisis (FFA), and of course the VGRtF themselves reaffirm the commitment to the right to food and the potential contribution of the respective CFS policy outcome to the progressive realization of this right.[7]
- A number of specific CFS policy recommendations, elaborated on the basis of previous HLPE reports, have explicitly included the right to food nexus into their content, see for example: the policy recommendations on forestry adopted in 2017;[8] the policy recommendations on livestock and sustainable agricultural development adopted in 2016;[9] the policy recommendations on water and food security and nutrition adopted in 2015;[10] and also the policy recommendations on connecting smallholders to markets adopted in 2016.[11]

Dimensions of right to food: According to international treaties of human rights there are two indivisible dimensions of right to food: the right to be free from hunger and malnutrition and the right to adequate food. Food for human beings should be understood as a process of nature transformation in healthy people and citizens (Burity *et al.,* 2010) .

The UN Special Rapporteur on the Right to Food articulated it in 2012 as: "The right to have regular, permanent and unrestricted access, either directly or by means of financial purchases, to quantitatively and qualitatively adequate and sufficient food corresponding to the cultural traditions of the people to which the consumer belongs, and which ensure a physical and mental, individual and collective, fulfilling and dignified life free of fear" (Zeigler, 2012). Some authors argue that the human rights framework articulated by the United Nations Human Rights Council can only be realized where the conditions of food sovereignty are ensured (Ishii-Eiteman, 2009).

[7] See: http://www.fao.org/cfs/home/products/en/
[8] See: http://www.fao.org/3/I8877EN/i8877en.pdf
[9] See: http://www.fao.org/3/a-bq854e.pdf
[10] See: http://www.fao.org/3/a-av046e.pdf
[11] See: http://www.fao.org/3/a-bq853e.pdf among others

Contribution of right to food to FSN: The concept of the right to food is embedded in a human rights framework and has been promoted by some groups to address structural factors that affect people's access and control over food, such as trade rules or access to land (Claeys, 2015; Bailey, 2018). Many state-based "right to food" initiatives have focused on social assistance to those without secure access to food (Claeys, 2015). The global food crisis in 2007—08 led to a reform of the CFS and placed the right to food at the centre of a strategy on FSN (De Schutter, 2012).

Innovation and innovation systems in right to food: 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).

<u>Food justice</u>

Brief description of food justice: Food justice is a concept and social movement that arose in the United States of America as part of a recognition of the systemic inequalities that create food insecurity, such as structural racism, sexism and widening gaps in income levels (Alkon and Agyeman, 2011). As an approach arising out of the urban poor, it forges 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 system to address FSN. Urban low-income communities with limited healthy food options in the United States of America with high numbers of people of colour living in them, for example, have been created through processes such as segregation, racist mortgage lending policies and the Highway Act (McClintock, 2011). Fast-food outlets with unhealthy, cheaper food options strategically market these products in these low-income neighbourhoods, leading to higher rates of overnutrition-related health outcomes such as diabetes and hypertension. Other food justice scholars and social movements have focused on farm workers in North America and other contexts, who are often subject to difficult working conditions and experience high levels of food insecurity due to trade and migration policies (Brown and Getz, 2011; Minkoff-Zern, 2012). Black farmers in the United States of America have been historically disenfranchised from land, extension support and other resources, but in some cases have worked to sustain food production despite these odds (White, 2010; 2017).

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. Food justice also focuses on sustainable food production, often encouraging organic or agroecological food production methods. Alkon and Agyeman (2011) note that food justice builds on the environmental justice movement, which sought to address disproportionate pollution and environmental degradation in low-income, marginalized communities. "While the environmental justice movement is primarily concerned with preventing disproportionate exposure to toxic environmental burdens, the food justice movement works to ensure equal access to the environmental benefit of healthy food." Food justice scholars and activists have criticized the ways in which organic and sustainably-produced local food is often unaffordable for low-income people of colour and have sought to create conditions in which healthy and environmentally sustainable food is accessible to these groups.

Contribution of food justice to FSN: Food justice initiatives aim to increase FSN for marginalized groups, including the urban poor, people of color, and farmworkers. The focus for food justice is on the FSN dimensions of access, availability, utilization and agency.

Innovation and innovation systems in food justice: <u>Several authors have noted strong</u> 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). 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). Examples of food justice that link to agroecology include African American farmers who grow food using agroecological methods and distribute their production to low-income peri-urban communities and urban farms that have youth training and employment opportunities in low-income African American communities (Gottleib and Joshi, 2009; White, 2010).

2.3.2 Sustainable intensification (encompassing Conservation Agriculture and Ecological intensification)

Brief description of sustainable intensification (and variations): 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's (2011a) definition in the Save and Grow publication, 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 are 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 conventional 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 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 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 optimizing application of external inputs (FAO, 2011; Bos *et al.* 2013; Friedrich *et al.* 2012; Matson *et al.* 1997; McCune *et al.* 2011; Pretty 1997, 2008).
- Minimize direct negative environmental impacts of food production (Royal Society London, 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, 2008; Ruben and Lee, 2000).

Objectives to 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 mentioned but not consistently or commonly. Sustainable intensification has also been described by the Montpellier Panel (2013) as having three "pillars":

- Ecological intensification: precision agriculture, building natural capital and diversification.
- Genetic intensification: conventional plant breeding, biotechnology and livestock breeding.
- Socio-economic intensification: enabling environments, building social capital and building human capital.

Specific practices promoted within these pillars of sustainable intensification include micro dosing, soil testing, seed spacing, water conservation practices, multiple and intercropping, agroforestry, and integrated pest management (under pillar ecological intensification); participatory plant breeding, hybridisation, biofortification, marker added selection, tissue culture, recombinant DNA, livestock cross-breeding, artificial insemination, and embryo transfer (under pillar genetic intensification); and under socio-economic intensification: inclusive agri-business chains, micro insurance, agricultural finance, value chains, agricultural cooperatives, and training, education and extension[12] (Montpellier Panel, 2013).

[12] See https://ag4impact.org/database/ and Agriculture for Impact 2014, No Ordinary Matter: conserving, restoring and enhancing Africa's soils. A Montpellier Panel Report, London.

Wezel *et al.* (2015) summarize the most common practices that appear in literature with sustainable intensification: 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; integrated pest management; soil conservation. More specifically mentioned are: use of worm composts, on-farm mechanization, smarter, precision technologies for irrigation and nutrient use efficiency, use of high yielding varieties including transgenic crops, and animal crop-integration.

Conservation agriculture

One other prominent approach that is aligned within the principles of sustainable intensification is conservation agriculture, having a very specific set of practices that correspond to those of sustainable intensification. The three distinct practices (sometimes called principles) of conservation agriculture (Hobbs *et al.,* 2008, FAO 2018[13]), all to be applied on a plot or field level are:

- apply minimum tillage and reduce soil disturbance (no-till, reduced till);
- maintain permanent soil cover with crop residues and living cover crops or mulches;
- apply crop rotations with different crops in the sequence.

One aspect of conservation agriculture practices that receives considerable attention is the no tillage management with direct seeding into cover crop mulches or crop residues. For this, there are different options to prepare for seeding (Triplett and Dick, 2008). One is to mechanically destroy the cover crop by rolling and bending it down and leave as mulch on the soil surface (Mirsky *et al.,* 2012). Another is to mechanically destroy the cover crop (mowing, chiselling, or rolling during frost – for non-frost resistant plant covers) and leave the cover crop residues on the soil surface. A third option, which is most used today, is to apply herbicide (mostly glyphosate) to the kill the cover crop before seeding.

Ecological intensification

Another elaboration of sustainable intensification, but one which has been developed as challenge to the technological focus of sustainable intensification, is ecological intensification. The original stated goal from Cassman (1999) is not very different from sustainable intensification ("further intensification of production systems that satisfy the anticipated increase in food demand while meeting acceptable standards of environmental quality"). However, more recent definitions have stressed the ecological aspects as in the often-cited CIRAD (2008) definition that ecological intensification refers to agricultural systems "designed to use ecological processes and functions for different purposes, such as biological control, invasive species management, and efficient use of resources and ecological services".

Ecological intensification principles generally include most principles of sustainable intensification, but also add more specifically: manage ecosystem services in production systems (Doré *et al.,* 2011; Bommarco *et al.,* 2012; Tittonell and Giller, 2013) and employ landscape approaches to achieve this (Tittonell, 2014), conserve biodiversity (Brussaard *et al.,* 2010), use biodiversity and key symbioses to improve soil fertility management (Agropolis, 2013; FAO, 2009), reduce pest and disease infestations in controlling and balancing the number of parasites and predators (Agropolis, 2013; FAO, 2009), and develop diversified plant breeding adapted to environmental constraints such as climate change and water shortage (CIRAD, 2008).

On a higher level of analysis, further principles of ecological intensification in relation to food systems and human factors include decrease energy use to reduce greenhouse gas emission and dependence on fossil fuels (Cassman, 2005; Doré *et al.,* 2011), recycle by-products (CIRAD, 2008), reduce meat consumption and food losses and waste (Bommarco *et al.,* 2012), reducing negative health and environmental externalities (Bommarco *et al.,* 2012; Doré *et al.,* 2011; Tittonell and Giller, 2013) and increase participatory involvement of stakeholders, building on local know-how and knowledge in the introduction of new practices (Caron *et al.,* 2014) and collective decision making (Tittonell, 2014).

Conservation agriculture has a long history of application, particularly in Latin America, while sustainable intensification and ecological intensification are newer concepts.

Contribution of Sustainable Intensification to FSN: The Montpellier Panel which ran between 2010 and 2016 as a collaboration between several networks, has embraced and promoted sustainable intensification and constructed a database providing information and case studies on the three pillars

[13] FAO 2018. Conservation agriculture. http://www.fao.org/conservation-agriculture/en/

(as described above) of the approach (https://ag4impact.org/database/). The reference database presents key innovations and practices of the approach, along with a discussion of benefits, costs and results. To characterise the contribution of sustainable intensification to FSN from the perspective of its adherents, the HLPE reviewed each innovation category under the three pillars and the relevant case studies presented on this site. Each innovation was scored for its contribution first to the different pillars or aspects of food security and nutrition, and secondly to the four operational principles of sustainable agriculture (HLPE, 2016). Out of 26 innovations or practices, the greatest majority (17) focused on increasing production, thus the Availability pillar. The next most common contribution (9/26) was to the Stability pillar, generally addressing the stability of production. Other aspects closely linked to FSN were less often addressed, or not at all, such as Water, Sanitation and Hygiene (WASH) and Infant and Young Child Feeding (IYCF). Some innovations recognized the need for Agency – for example, the focus on agroforestry recognizes the need for land tenure and rights over natural resources. Building of social capital was often approached through market-based interventions and creating agricultural value chains, as illustrated in case studies of a commercial farmers' association in Uganda, which was assisted to build a warehouse, procure fertilizers and hire extension officers, to support delivery on a contract with the World Food Programme.[14] From our analysis of the abovementioned Sustainable Intensification database , the 26 aspects and innovations featured in this database innovations contributed equally and strongly to Resource Efficiency and to Resilience (both 12/26), to Environmental footprint (10/26) with relatively few contributing to Social equity/responsibility.

Innovation and innovation systems within Sustainable Intensification: Innovation and innovation systems, as presented above, derive from value systems, world views and orientations. Innovative approaches in sustainable intensification are oriented toward the perceived imperative to address hunger and malnutrition through increasing productivity; but in departure with the past Green Revolution approaches, innovations are also aimed toward doing so with greater efficiency, 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. 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.

Conservation agriculture, with its long history of adoption particularly in Latin America, has a well-developed innovation or dissemination system, often based on farmer associations and forging linkages with the suppliers of the needed machinery and inputs.

Innovation systems in ecological intensification, on the other hand, focus on using and developing ecological processes for generating ecosystem services within the production landscape, and reorienting the food system to reduce waste and encourage sustainable systems of consumption. Local knowledge, with its understanding of the context-specific ecological and socio-economic conditions, is a key starting point for innovations.

[14] https://ag4impact.org/sid/socio-economic-intensification/creating-enabling-environments-2/inclusive-markets/

2.3.3 Organic agriculture

Brief description of organic agriculture: Organic agriculture is a production system that relies on ecosystem management and aims to reduce external agricultural inputs. 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) that increases farmers' income and reduces external input costs (Jouzi *et al.,* 2017). Field trials have shown that organic systems have relatively high yields with a favorable input–output efficiency (Forster *et al.*, 2013). According to Jordan *et al.* (*,* 2009), organic farming increases soil organic carbon content through recycling organic residues produced on the farm back to the soil, thereby contributing to climate change mitigation, while ensuring food security. It also offers a means to address food self-sufficiency, and nature conservation.

Interest in organic agriculture has been increasing in many countries. According to the latest available data 50.9 million hectares worldwide are under organic agricultural management (Willer and Lernoud 2017). For example, in North America 3 million ha, Latin America 6.7 million ha, Europe 12.7 million ha, Africa 1.7 million ha, Asia 4.0 million ha, and Oceania 22.8 million ha lands are under organic agriculture (Willer and Lernoud 2017). Globally, 2.4 million organic producers were reported and among them most of producers are located in developing and transition countries. However, some crops reach much higher shares. For example, the organic coffee area represents almost 9 percent, and for organic olive production it is 6.5 percent of the total world agricultural area. The agricultural lands used in Australia and Oceania have almost half of the world's organic lands, followed by Europe with 12.9 million ha (Willer and Lernoud, 2017).

The worldwide market for organic products was estimated to reach US$ 64 billion in 2012, an increase of 156 percent compared to a decade earlier (FiBL & IFOAM, 2014), whereas farmers from developing countries gain more profit. Crowder and Reganold (2015) show in their meta-analysis that organic production is on average economically more profitable for farmers than conventional farming, however, only when the economic premium is included. Breakeven premiums necessary for organic profits to match conventional profits are estimated to only 5–7 percent, even with organic yields being on average 10–18 percent lower. However, the meta-analysis did not account for either environmental costs (negative externalities) or ecosystem services from good farming practices; accounting for these would favour increased profits in organic agriculture. Organic farming is a cost-effective system that uses natural resources and is considered as a feasible option for small farmers to increase their income (Kleiman, 2011).

Principles of organic agriculture: Organic agriculture is based on principles and management practices that do not have adverse effects on the environment, such as: improved and/or decreased fertilization to lower nutrient losses; management to improve plant and soil nutrients through biological nitrogen fixation; maintenance of long-term soil fertility by enhancing soil biological activity; biological control of plant disease, and use of soil organic amendments, but also prohibition of the use of chemical fertilizers, pesticides and herbicides (Tourist *et al.,* 2012; Bhardwaj *et al.,* 2014, Migliorini and Wezel 2017, Seufert *et al.,* 2017).

Contribution of organic agriculture to FSN: There is still much debate about whether organic agriculture can produce sufficient food to feed the increasing world population that might require more land than with conventional agriculture (de Ponti *et al.,* 2012, Muller *et al.,* 2017). Other systematic reviews found in average 8–25 percent lower yield in organic compared to conventional systems (Pension *et al.,* 2015; Regan old and Wachter, 2016). More importantly, Ponisio *et al.* (2015) found entirely different effects of crop types and management practices related to the yield gap compared with previous studies. For example, they found no significant differences in yields for leguminous versus non-leguminous crops, perennials versus annuals or developed versus developing countries. Instead, two agricultural diversification practices, multi-cropping and crop rotations, substantially reduce the yield gap (to 9 ± 4 percent and 8 ± 5 percent, respectively) when the methods were applied in only organic systems.

The contribution of organic farming to other aspects of FSN, such as stability, may differ somewhat amongst geographic locations, as do organic farming approaches. For example, due to high disease pressure rates in the humid tropics, and lower soil nutrient concentrations in arid regions and water shortage limiting crop productivity (Giller *et al.,* 2011; Lee *et al.,* 2015; van Bruggen *et al.,* 2016), organic agriculture in the tropics must be oriented to address these challenges. The most vulnerable region in the world due to climate change is Africa, and new organic management approaches are required to increase crop yields, increase resilience and combat food insecurity (Wheeler and von

Braun, 2013). The main opportunities of organic farming in developing countries includes environmental benefits that improve soil and plant health and biodiversity conservation and reduce energy consumption and greenhouse gas emissions (Gattinger *et al.,* 2012; Tuomisto *et al.,* 2012; Jouzi *et al.,* 2017).

The health benefit of organic farming relates to the reduction of toxic chemicals and nitrate in the food supply (Lairon, 2010) and also reduces these health hazards to farmers and their families. Studies have found that organic foods have significantly lower levels of pesticide residues compared to conventionally-produced foods, and that children who consume organically produced foods have lower levels of organophosphate pesticide metabolites in their urine (Reganold and Wachter, 2016). The American Academy of Pediatrics (2012) reports that an organic diet reduces children's exposure to pesticides. The ban of the many plant protection chemicals like pesticides, including herbicides, is a one of the consistent approaches of organic farming, that rely on preventive and ecological measures to regulate pests and diseases in crops and livestock.

From an ecological standpoint, the species richness and abundance of biodiverse organisms has been shown to be improved by organic farming compared with intensive conventional farming (Bengtsston *et al.*, 2005).

Despite such benefits of organic farming, there are also some challenges that include high plant disease rates, nutrient management and certification issues. Using organic techniques is knowledge-intensive, which is a challenge where there is limited access to education and information (Seufert *et al.,* 2012; Connor *et al.,* 2013; Chiputwa *et al.,* 2015; van Bruggen *et al.,* 2016). Importantly, there is limited research on FSN outcomes from organic production systems for smallholders and other marginalized groups (Seufert *et al.,* 2012; Ponisio *et al.,* 2015).

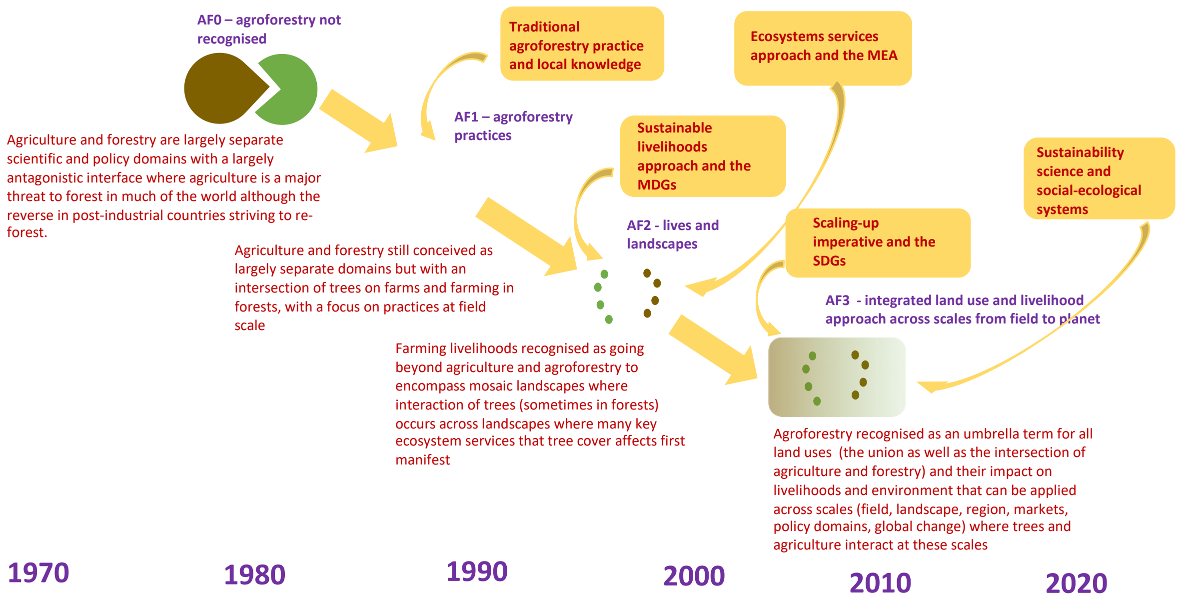
Innovation and innovation systems in organic agriculture: During the last decades, innovative technologies that have increased agricultural productivity and contributed to food security have been developed through disciplinary research, e.g. plant and animal breeding, plant biotechnology, agro-technological approaches. Inter-and-transdisciplinary research between plant, soil, animal sciences, agroecological engineering, sociology, and economics has also contributed to such increases. (Forster *et al.*, 2013). Organic agriculture, while often not the focus of this research, has benefited from many advances and has been open to these forms of innovation, including the smart use of novel technologies such as molecular-based breeding, and forms of biotechnology which improve production with minimal environmental impact. At the same time, the contribution of organic farming systems to FSN will be greatly enhanced through greater investment in innovations including integrated farming, conservation agriculture within organic principles, agrobiodiversity, agroforestry and organic livestock rearing which can reduce food waste, improve plant-based diet, and food distribution, as well as environmental sustainability (Reganold and Wachter 2016).

2.3.4 Agroforestry

Brief description of agroforestry: Put simply, agroforestry is where trees interact with agriculture (Sinclair, 2004). This may occur at field, farm, livelihood, landscape or planetary scales and represents an approach to achieving sustainable intensification of agriculture and improved nutrition through harnessing ecosystem services provided by trees. Major types of agroforestry include silvoarable (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), multistrata production practices (including homegardens), woodlots on farms and various other ways that trees in agricultural landscapes impact agriculture and rural people's livelihoods (Sinclair, 1999).

Although an ancient practice, agroforestry emerged on the world stage as both a scientific discipline and a development imperative in the 1970's marked by the creation of the International Council for Research Agroforestry (ICRAF) in 1978, which later became a centre within the CGIAR partnership, and is now known as the World Agroforestry Centre. Since then the conceptualisation of agroforestry has evolved alongside major shifts in thinking about food systems and the environment to embrace larger scales and a more explicit transdisciplinary focus (**Figure 7**). Three major transitions have been recognised (van Noordwijk *et al.*, 2017) from a starting point where agroforestry was traditionally practised but not recognised scientifically or in the government policy (AF0), through periods where the focus was first on specific practices where trees and agriculture interact at field and farm scale (AF1), then how trees impact lives and landscapes (AF2) and most recently embracing an integrated land use and livelihood approach applied across scales from that of the field to the whole planet (AF3). Agroforestry is widespread with more than 10 percent tree cover on over 45 percent of agricultural land globally, estimated to have sequestered 0.7 Gt CO_2 per year between 2000 and 2010 that did not appear in national inventories (Zomer *et al.*, 2016).

Figure 7 Evolution of the agroforestry paradigm

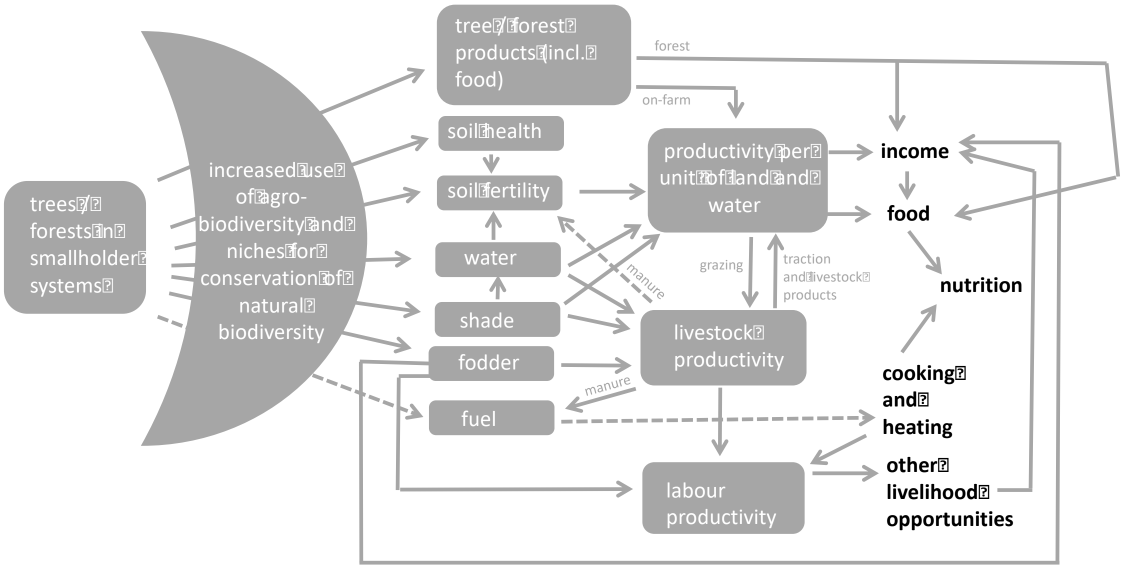


Source: Adapted from Van Noordwijk *et al.*, 2017

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 either without causing environmental degradation (Anderson and Sinclair, 1993) or while restoring degraded land (Crossland *et al.*, in press). This has both ecological and economic dimensions associated with more functionally diverse production practices leading to greater resilience (Dumont *et al.*, 2017), reconciling achievement of UN sustainable development goals (SDGs) 1 and 2 (to end poverty and hunger) with protection of the environment (SDG 14). Trees are often helpful to farmers in adapting their agriculture to climate change, with agroforestry prominent in advice to national governments on climate change mitigation and adaptation (Dinesh, 2016).

In addition to direct contributions to diet and income from tree products, much of the contribution that trees make to agricultural production systems is through system intensification involving interactions with other livelihood components (**Figure 8**). Farmers are concerned about the total factor productivity of their whole livelihood, including how labor is used across agricultural and non-agricultural opportunities. This needs to be taken into consideration for agroforestry innovations to be adopted and viable within the livelihood context that they are intended for (Sinclair, 2017). For example, on-farm tree fodder production can increase livestock productivity whilst reducing labor required to collect fodder, freeing labor and time for other additional paths to intensification (Franzel *et al.*, 2014). In some contexts, FSN is constrained by lack or shortages of fuel to cook, or dung is used as fuel. On-farm firewood production alleviates the fuel constraint, allows dung to be used as fertilizer, increasing soil fertility and crop yield, and frees up labor (Duguma *et al.*, 2014). Such knock-on effects can often be as or more important than direct benefits from tree products. Trees can also play a key role in restoring and maintaining soil health because they are associated with higher abundance and activity of beneficial soil organisms, as well as contributing to soil fertility through tightening nutrient and water cycling, improving nutrient and water use efficiency and thereby closing yield gaps of staple food crops (Barrios *et al.*, 2012). Groundwater recharge in the seasonally dry tropics is maximized with an intermediate level of tree cover across agricultural landscapes (Ilstedt *et al.*, 2016).

Figure 8 Major ways in which agroforestry impacts smallholder livelihoods



Source: Adapted from FTA, 2017.

Contribution of agroforestry to FSN: Contributions of agroforestry to FSN have been quantified for some agroforestry practices in some regions but there is no overall quantification of the global contribution. Meta-analysis across sub-Saharan Africa showed that fertilizer trees produced a mean maize yield increase of 1.3 and 1.6 t ha^{-1} for non-coppiced and coppiced fertilizer tree systems, respectively over farmers conventional practice of unfertilized sole maize (Sileshi *et al.*, 2008). Over half a million farmers have adopted fertilizer trees systems in southern Africa (Zambia and Malawi), resulting in between 57 and 114 extra person days of maize consumption per household per year, improving the food security of over 2.5 million people (Ajayi *et al.*, 2011). Subsequent analysis of maize yield in four different agroforestry practices nationally across Malawi revealed large variation in performance amongst farms (5-8 fold with the top 20 percent of farmers achieving yield increases of over 2 t ha^{-1} yr^{-1}), indicating the scope for increasing both food yield and adoption through better matching practices to context and developing a supportive enabling environment (Coe *et al.*, 2016).

There is 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 (Icowitz *et al.*, 2014). Fruits, nuts, fungi and vegetables from trees are a crucial source of micronutrients in many rural and smallholder communities, and often provide a major contribution to cash income at the household level. Dietary diversity was found to be 12–14 percent higher in households practicing farmer managed natural regeneration of trees (FMNR) than those who did not across four countries in the Sahel (Binam *et al.*, 2015). There is a recent regreening in many places across the Sahel through the use of FMNR that covers over 5 million ha of Niger alone. Recent research has shown that it is possible to exploit differences in phenology of fruit tree species to provide critical nutritional supplement (particularly of Vitamins A, C and B6) and maintain dietary diversity throughout the year (Dawson *et al.*, 2013), even in dry environments where extensive tree root systems and water storage in succulent roots allow trees to be productive at times in the year when herbaceous vegetation cannot supply this nutritional diversity without irrigation (Luedeling *et al.*, 2016). In Machakos in Kenya an average household can achieve year round dietary diversity with 20 trees of 10 species either dispersed throughout their farm (on borders, around the home and in fields) or in a 8 m x 18 m (0.015 ha) fruit orchard (Kehlenbeck *et al.*, 2015).

Innovation and innovation systems within agroforestry: From the outset of agroforestry science four decades ago, local knowledge was recognized as a key resource because, while there was sparse scientific knowledge about tree-crop-animal interactions, there was a rich body of experience amongst 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 (**Figure 7**) 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, 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). This was done to accelerate the scaling up of agroforestry adoption by addressing the heterogeneity of farm conditions and farmer circumstances. 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).

2.3.5 Climate smart agriculture

Brief description of 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. One such approach is climate smart agriculture (CSA), which has seen transformation and reorientation of existing agricultural systems and technologies to address FSN and environmental challenges. According to FAO (2010), 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 of food, feed, fuel and fibre in a changing climate.

Principles of climate smart agriculture: The concept of climate smart agriculture is increasingly being recognized as a major entry point to 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).

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 (adapted from FAO, 2010 and Lipper *et al.,* 2014)

<u>Contribution of CSA to FSN:</u>

CSA seeks to:

- address FSN challenges;
- maintain and enhance agricultural productivity;
- meet household, national, regional and global food demands despite threats posed by climate variability and change;
- contribute to poverty reduction;
- reduce vulnerability;
- reduce the ecological footprint;
- promote and safeguard agrobiodiversity;
- be inclusive engaging women and marginalized groups;
- promote synergies and reduce trade-offs.

Innovation and innovation systems in CSA: 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 conditions including climate and soils, socio-economic 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 policies, institutions 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). It has been suggested that more investigation of the aspects of mitigation, in site-specific contexts, and the trade-offs and synergies between objectives is needed. (Saj *et al.* 2017). It has been noted by the same authors that agroecology has much to offer in terms of site-specific adaptation measures.

While still a relatively new concept, the aims and objectives of shifting to CSA are known to differ according to level of implementation, and this has seen a seen a lot of CSA innovations tailored to suite the heterogeneous environments under which agriculture operates. At field and/or farm-level, the focus usually to strengthen livelihoods and food security of local farmers, by adopting appropriate approaches (adaptation) and technologies for agricultural production (productivity) (Williams *et al.*, 2015) though with little emphasis on mitigation (Saj *et al.* 2017). Common farm-level examples of CSA practices and approaches include mixed cropping integrating legumes and cereals, agroforestry, conservation agriculture, reduced deforestation, improved pest and disease management, efficient use of crop production resources, clean energy and matching varieties to local climate among others. At national level, the thrust of CSA shifts more to focus on enabling policies anchored on the necessary technical and financial mechanisms to mainstream climate change adaptation and mitigation into agricultural sectors. This is meant to provide a basis for operationalizing sustainable and climate resilient agricultural development under a changing climate, embracing all the necessary key players using an innovations systems approach. Although it has been suggested that poor uptake of CSA by farmers could largely be attributed to a lack of technical know-how, capacity and financial solutions to sustain implementation, (Williams *et al.* 2015) , recent evidence point towards a general failure to recognize CSA practices at different operational scales. There may be a need to come up with a more practical definition for the concept to be embraced by developmental organizations and civil societies (Saj *et al.,* 2017).

2.3.6 Permaculture

Brief description of permaculture: Permaculture can be defined as an alternative agriculture movement based on 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. Moreover, 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, 2003). Originally proposed by Bill Mollison (Ferguson and Lovell 2014[vi]), 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. There are many permaculture centres in different countries and in all continents.

Notwithstanding the conceptual novelty of proposing new principles to design and manage agricultural systems, the idea of producing food and other materials mimicking natural patterns is not necessarily new. In different parts of the world traditional populations and peasants have been designing productive systems based on natural ecosystems patterns. There are many examples all over the world such as traditional agroforestry systems in Indonesia (Michon and de Foresta, 1997; Thiollay, 1995), indigenous people in Brazil managing the forest (Posey, 1985), cocoa forests in Africa (Oke and Odebiyi, 2007), among many other examples.

Principles of permaculture:

Permacultural 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; and
- setting limits to population and consumption.

While the design principles are, respectively, the following:

- observe and interact;
- catch and store energy;
- obtain a yield;
- apply self-regulation and accept feedback;
- use and value renewable resources and services;
- produce no waste;
- design from patterns to details;
- integrate rather than segregate;
- use small and slow solutions;
- use and value diversity;
- use edges and value the marginal; and
- creatively use and respond to change.

In many ways permaculture methods and practices can be classified as forms of agroecology (Hathaway, 2016). In fact, permaculture can be categorized as one of the multiple schools of alternative agriculture under the encompassing concept of agroecology (Guzmán and Woodgate, 2013). Similarly, 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, integration of livestock and crops, recycling nutrients, avoiding chemical inputs such as pesticides and fertilizers, maximizing biodiversity, and improving soil health (Hathaway, 2016). Moreover, permaculture is also responsive to the human dimension and to some extent to social justice and an ethical relationship between humans and the environment, as one of its core values is precisely “care for the people” (Veteto and Lockyer, 2008; Holmgren, 2002; Ferguson and Lovell, 2015).

Contribution of Permaculture to FSN: Despite the scarce literature about FSN specifically related with permaculture, there is evidence indicating that such approach has an important contribution in this respect. Many recent studies associating agroecological approaches with FSN point that it is possible to enhance agricultural production while increasing the adoption of sustainable methods (Badgley *et al.,* 2007; Pretty, 1999, 2009; Scialabba, 2007). In addition, as FSN is strongly related with how people have access to food, and permacultural approaches claim for the design of human systems where access to food is an imperative.

One of the caveats that may be associated with permacultural approaches is related to the complexity of the concept. The whole idea of designing an agroecosystem taking into consideration many aspects and factors related to landscape, fluxes of energy, species dynamics, interactions among biotic and abiotic components, and production of food among other elements is not that simple. A holistic approach of food production considering the multiple aspects involved in the food chain is still a challenge, even considering the urgency to promote sustainable production systems. Another limitation is related to labour, as many of the permacultural systems are difficult to mechanize and require intensive work. Finally, another hindrance to the adoption of such practices it is a challenge to the predominant idea of maximizing production rather than optimizing the use of available resources for agricultural production.

Innovation and innovation systems in Permaculture: In many ways Permaculture represents an innovative production system, particularly for FSN. The concept of designing whole production systems based on a holist approach emphasizing landscape patterns, functionality and species assembly represents a progress towards SFSs. Moreover, permacultural 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. Also, intrinsically innovative is the notion that it is possible to produce high quantity of food and materials in any given place with minimum external inputs, which is particularly relevant for FSN.

2.3.7 Nutrition sensitive agriculture

Brief description of 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, 2014). The approach recognizes that nutritious food is essential for wholesome nutrition, acknowledges the social and economic significance of food and agriculture for rural communities, and nutrition education to help address health outcomes. The term ”nutrition sensitive agriculture” gained increased attention in the last two decades, following several reviews that examined the evidence for agricultural interventions having a positive impact on nutrition (Shekar *et al.,* 2013). Nutrition-sensitive agriculture 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).

Characteristics of Nutrition-Sensitive Agriculture: Nutrition-sensitive interventions and programmes aim to tackle the underlying determinants of child nutrition, namely: FSN; care-giving at the maternal, household and community levels; access to health services and a safe and hygienic environment (Ruel and Alderman, 2013). Nutrition-sensitive interventions include agriculture and FSN, social safety nets, women’s empowerment, education, maternal mental health, early child development, water and sanitation, and health and family planning services (Ruel and Alderman, 2013).

Contribution of nutrient-sensitive agriculture to FSN: Reviews of agricultural interventions’ impact on nutrition consistently found that those programmes that promote crop diversity, small livestock rearing, dairy production or micronutrient-rich crops can improve FSN and household dietary diversity (Ruel *et al.,* 2018). Those programmes that included nutrition education and focused on gender equity and empowerment in agriculture were significantly more likely to lead to improvements in child and maternal nutritional status (Malapit *et al.,* 2015, Malapit and Quisumbing, 2015; Ruel *et al.,* 2018). At the same time, it should be recognized that many studies had serious methodological limitations, such as poor research designs, low sample sizes, limited duration or incorrect age groups for measuring impacts on child growth outcomes, and a higher quality of research is needed (Arimond *et al.,* 2011; Berti *et al.,* 2004; DFID, 2014; Fiorella *et al.,* 2016; Leroy *et al.,* 2008; Masset *et al.,* 2012; Pandey *et al.,* 2016; Randolph *et al.,* 2007; Ruel, 2001; Webb-Girard *et al.,* 2012; Webb and Kennedy, 2014). One strategy to transition to nutrition-sensitive agriculture is to measure nutritional yield, which takes into account the nutritional quality of agricultural production (DeFries *et al.,* 2015).

Homestead food production programmes include promotion of home gardens with micronutrient-rich legumes, vegetables and tubers (which can include biofortified crops). Some programmes also integrated small livestock such as poultry (Kumar *et al.,* 2018; Murty *et al.,* 2016). These programmes often include an explicit focus on nutrition education and gender equity, including direct transfer of agricultural inputs and training for women (Ruel *et al.,* 2018). There are also goats and dairy cattle focused programmes, which aim to reduce poverty and increase production and consumption of animal-sourced foods and measure nutritional outcomes. Such programmes often include attention to gender inequities and enterprise development (Miller *et al.,* 2014; Rawlins *et al.,* 2014).

Biofortification involves increasing the density of minerals and vitamins in crops through plant breeding, transgenic methods or agronomic practices (Bouis and Saltzman, 2017). Conventional plant breeding includes the development of beta-carotene-rich ”orange-fleshed sweet potato”, iron-rich beans, rice and pearl millet, which have shown strong promise of nutritional impact (Finkelstein *et al.,* 2017; Hotz *et al.,* 2012a,b; Mondal *et al.,* 2016). Transgenic breeding is being done with beta-carotene in rice (i.e. “Golden rice”) (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). Biofortification using conventional breeding methods has shown strong promise of nutritional impact but have not compared to the diversified diets approach (Finkelstein *et al.,* 2017; Hotz *et al.,* 2012a,b). Transgenic approaches have to date shown more modest evidence of impact and limited testing (Bouis and Saltzman, 2017; Finkelstein *et al.,* 2017). Thus far the evidence is limited for agronomic practices such as increased Zn fertilizer to increase Zn in wheat, having direct impact on nutritional outcomes.

Irrigation programmes and other technological changes in agriculture can have both positive and negative impacts on nutrition, through several pathways: increasing food production and diversity of crops, increased income from market sales, women's empowerment (or disempowerment) through increased control over a key asset, and worsened health outcomes from polluted water via agrochemicals, livestock manure or vector-breeding habitat (Domènech, 2015; HLPE 2015). Few irrigation programs have explicitly focused on nutritional outcomes (Ruel *et al.,* 2018). Earlier studies showed that irrigation programmes that do not take social inequities into account can worsen nutrition and FSN outcomes, for example by increasing women's workload while shifting control of land and assets to men (Carney, 1993; von Braun *et al.,* 1989; Webb, 1989). One recent study in Benin of a program that used solar-powered drip irrigation systems on market gardens for two women's groups increased dietary diversity and income by increasing more diverse diets over a longer period and increased market sales (Alaofè *et al.,* 2016).

Value chains refer to the addition of economic value for different members of a food supply chain, including producers, processers and retailers. 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, 2014). Nutrition-sensitive value chain interventions include promotion and sale of nutritionally-rich food products such as micronutrient-fortified yoghurt or poultry. There are limited impact studies of nutrition-sensitive value chains to date (Ruel *et al.,* 2018). One study in Senegal of a dairy value chain, in which dairy producers received micronutrient-fortified yoghurt, and received nutrition education, found improved child nutritional outcomes with dairy groups participating in the value chain (Le Port *et al.,* 2017). Consumption of orange sweet potato with high levels of beta-carotene improved the vitamin A status of children in primary schools in Africa (van Jaarsveld *et al.,* 2005).

About a third of the agricultural production intended for food use does not enter the food supply chain, making the recovery of food loss and waste (FLW) an important consideration for food-based nutrition-sensitive value chains (HLPE 2014). FLW along the whole food supply chain from farm to consumer should be considered. For example, this is being promoted in the food supply chain in Denmark and involved civil society groups with governmental support and industry (Halloran *et al.,* 2014) and explored in the dairy value chain in Uganda (Wesana *et al.,* 2018). The success of this approach will depend on stakeholders along the chain paying more attention to nutritive-sensitive value chains.

Women's empowerment in agricultural programmes are another "nutrition-sensitive" approach to improving nutrition and food security. Women's empowerment is defined as "the expansion in a person's ability to make strategic life choices in a context where this ability was previous denied to them" (Kabeer, 1999; Ruel and Alderman, 2013). Several reviews have shown that women's empowerment, via control over assets, decision-making, time use, mobility and leadership, has positive outcomes for nutrition, although these outcomes are context specific (Carlson *et al.,* 2015; Cunningham *et al.,* 2015; Pratley *et al.,* 2016). A new standardized measure, Women's Empowerment in Agriculture, has led to an increase in studies examining the relationship between gender relations and nutritional outcomes (Alkire *et al.,* 2013). Four studies have shown increasing women's empowerment has had significant improvements in child and maternal nutritional outcomes, through various means, including increased decision-making power over production, control over income and reduced workload (Sraboni *et al.,* 2014; Cunningham *et al.,* 2015; Malapit *et al.,* 2015; Malapit and Quisumbing, 2015). Increasing women's labour in agriculture, in contrast, can also have negative outcomes for nutrition (Ruel *et al.,* 2018).

Social safety nets, which provide cash or food to low-income households, are another form of nutrition-sensitive intervention that can significantly affect FSN (HLPE 2012). Some programmes link the cash transfers to health, education and nutrition services, distribution of food or supplements, specifically target women or populations facing climatic or economic stresses. Conditional cash transfers have had mixed impacts on nutrition, with longer programmes focused on the youngest and poorest programmes being the most effective (Leroy *et al.,* 2009). Many countries have school feeding programmes, which have shown to have small effects on child nutritional status, both positive and negative, due to risks of obesity, depending on the type of food provided. There are a number of large-scale social safety net programmes in many countries, with between 0.75 to 1 billion people currently receiving cash transfers (Ruel *et al.,* 2013). In Mexico and Brazil these conditional cash transfer programmes reach 25 percent of the country's population. The Mexican programme has shown positive impacts on children's intake of iron, zinc and vitamin A and reductions in low birthweight

(Barber and Gertler, 2010; Leroy *et al.,* 2010; Ruel *et al.,* 2013). At the same time, the supply of food to families with high prevalence of overweight and obesity at baseline led to increases in obesity rates among women (Leroy, 2013). In the case of Brazil, there has been a deliberate link between the Bolsa Familia cash transfer programme with farmers' markets as a means to boost farmers' income while providing low-income families with increased food (Rocha, 2009; Chappell, 2018).

Education is another means by which FSN can be improved. Parental education, particularly maternal education, has been demonstrated to be the second most significant driver of child nutritional status, after safe water (Smith and Haddad, 2015; Semba *et al.,* 2008; Ruel *et al.,* 2013). Schooling increases income in the long term, which can increase FSN (Ruel *et al.,* 2013). There is also evidence that early child educational programmes, which focus on psychosocial stimulation, responsive parenting and addressing maternal poverty, can have positive impacts on child nutritional status (Engle *et al.,* 2007, 2011; Bhutta *et al.,* 2013).

Innovation and Innovation Systems within Nutrition Sensitive Agriculture: While there is not a set of innovation systems across all nutrition-sensitive agriculture approaches, some key innovation systems include addressing gender inequalities, social protection and education. Women's status and involvement in agriculture are often key mediators of FSN through multiple pathways, including access and control over resources and assets, allocation of food, health and care, time use and women's own health and nutritional status (Ruel *et al.,* 2013). Innovative social protection programs strengthen FSN for both producers and consumers through public policies. In the case of Brazil, for example, there has been a deliberate link between the Bolsa Familia cash transfer programme with farmers' markets as a means to boost farmers' income while providing low-income families with increased food (Rocha, 2009; Chappell, 2018). Educational strategies are another innovation system which FSN can be addressed. 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 effectively to integrate agriculture, social equity and nutrition with positive food security, nutrition and sustainability outcomes (Bezner Kerr *et al.* 2010).

2.3.8 Sustainable food value chains

Brief description of 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, 2014). 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). SFVC is an approach that has been put into practice by many initiatives of small farmers and the private sector around the world, for example, with respect to potato value chain in India (FAO, 2009; Reardon *et al.,* 2012; The Hindu Business Line, 2012); the pineapple value chain in Ghana (Webber, 2007; Blue Skies, 2010, 2012; GIZ, 2011; Wiggins and Keats, 2013); beef value chains in Namibia (van Engelen *et al.*, 2012; FAO, 2013a); vegetable value chains in the Philippines (Concepcion *et al.*, 2007; Sun Star, 2011a, b); and tea value chains in Kenya (CPDA, 2008; Knopp and Foster, 2010; FAO, 2013b). VCs typically cover a country's entire product subsector (e.g. beef, maize or salmon). Added fiscal value and sustainability can be reflected in multidimensional performance measures.

Characteristics of Sustainable Food Value Chains: The sustainability of the VC has simultaneous influences along economic, social and environmental dimensions. A VC is considered economically sustainable when: actors in the chain are commercially viable (i.e. profitable for commercial services) or fiscally viable (for public services).

Sustainability is recognized in terms of the social dimension when outcomes are socially and culturally acceptable in relation to distribution of the benefits and costs associated with the increased value creation. To fulfill the environmental dimension of a sustainable VC, there must be little or no negative impact on the natural environment from their value-adding activities of VC actors (FAO, 2014).

Contribution of sustainable food value chains to FSN: Value chains (VCs) are dynamic, market-driven vertically coordinated systems, with potential to enhance the sustainability of agricultural systems and that improve FSN and reduce inequities for rural populations (Swisher *et al.* 2017). Implicit in the sustainability element is a more equitable distribution of the increased value added and reduced use of non-renewable resources, as these are becoming increasingly important determinants of market access and competitiveness (FAO, 2014). Thus, sustainable food value chains can contribute to the FSN dimensions of access, and with equity concerns, to agency.

Box 8 Example of sustainable food value chain: Freshveggies PGS in Uganda

To be developped

Source: Loconto *et al.* 2018.

The HLPE (2017) report on Nutrition and Food Systems included in its conceptual framework of "food systems for diet and nutrition" a component on food supply chains. This is envisioned to be composed of production systems (farmers, indigenous peoples, agribusiness, land owners, fisheries and financial entities); storage and distribution actors (transporters, agribusiness, distributors); the processing and packaging sector (comprising packing plants, the food and beverage industry, small and medium enterprises) and the retail and market sector (retailers, vendors, food outlet owners, traders, restaurateurs and wholesalers). In the context of this report, we note that a sustainable food value chain framework is made up of these elements, but also (from the standpoint of sustainability) should include the initial stage of inputs and equipment (FAO, 2014), a stage that is critical to sustainable food production, and ultimately the final stage of consumers.

Innovation and innovation systems within sustainable food value chains: 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-input and food retail (IPES-Food 2016; Howard 2016). The high costs of inputs in conventional or industrial agriculture contributes 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). While some argue that rural economies may be strengthened when some producers specialize and achieve economies of scale and play a more complementary role within the chain (Cucagna and Goldsmit, 2018), others suggest that reducing the power and highly distorted markets in many agrifood industries is critical for ensuring viable livelihoods for producers (IPES-Food 2016; 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 2010Loconto *et al.* 2018). These farmers may have systems thinking needed for effective networking aspirations, but are constrained by time, resources and a sense of agency (understood as the subjective awareness of an individual's capacity to take action). 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 (Loconto *et al.* 2018). These strategies will require a change in the mind-set of various actors and behaviour towards collaboration (Dania *et al.,* 2018). A good governance structure is a critical element of sustainable VC; 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, 2014). One innovation in sustainable food value chain include 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 (IFOAM 2016). It is estimated that PGS are found in 72 countries, and well-established in 20 countries (see Boxes 8 and 9).

Box 9 Participatory Guarantee System in Bolivia linked to institutions - Tarija School Feeding Program

To be developed.

Source: Loconto *et al.* 2018

The development of food VCs thus has to go hand in hand with the development of other infrastructures or VCs that have clearly identified market-growth opportunities and that can create large numbers of decent jobs. In some cases public investment is needed to support local or regional nested market networks, which have arisen in response to market failures. The unlocking of greater value from agricultural production is expected to be a contributor to a sustainable food value chain. This is possible because consumers are seeking premium high-quality products for their health and well-being, produced using environmentally and socially responsible manufacturing processes (CSIRO, 2017). The consumer demand for food safety and quality has led to the development of new value-added differentiated food products, which has created value for the food chains.

Sustainable food value chain approaches provide a flexible framework to effectively address many challenges facing food system development. In practice, a misunderstanding of its fundamental nature can easily result in limited or non-sustainable impact. Even if practitioners understand and rigorously apply the economic, social and environmental characteristics of sustainable food value chains, this approach cannot solve all problems in the food system. Food VCs cannot provide incomes for everyone, cannot incorporate trade-offs at the food-system level and cannot entirely avoid negative environmental impacts. Public programmes and national development strategies are needed to address these limitations. However, such programmes and strategies are largely financed through tax revenues generated in value chains, thus placing value chain development in general, and sustainable food value chains in particular, at the heart of any strategy aimed at reducing poverty and hunger in the long run.

2.4 Reducing food losses and waste

Because of its importance as a cross cutting issue identified from **Table 3** (Section 2.1.2) the reduction of food loss and waste is elaborated here.

Contribution of reducing food losses and waste (FLW) to FSN: 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 per annum is wasted. This is one-third of food produced for human consumption or a quarter of calories produced that does not enter the human food supply, as it is either lost or wasted from the food supply chain (Gustavsson *et al.* 2014; 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 energy that has gone into the production of the food (Cuellar *et al.*, 2010).

Definition 3 Definitions of Food Losses, Food Waste & Food Quality Loss or Waste

Food loss and waste (FLW) refers to a “decrease, at all stages of the food chain from harvest to consumption in mass, of food that was originally intended for human consumption, regardless of the cause.”

Food losses (FL) refers to a “decrease, at all stages of the food chain prior to the consumer level, in mass, of food that was originally intended for human consumption, regardless of the cause.”

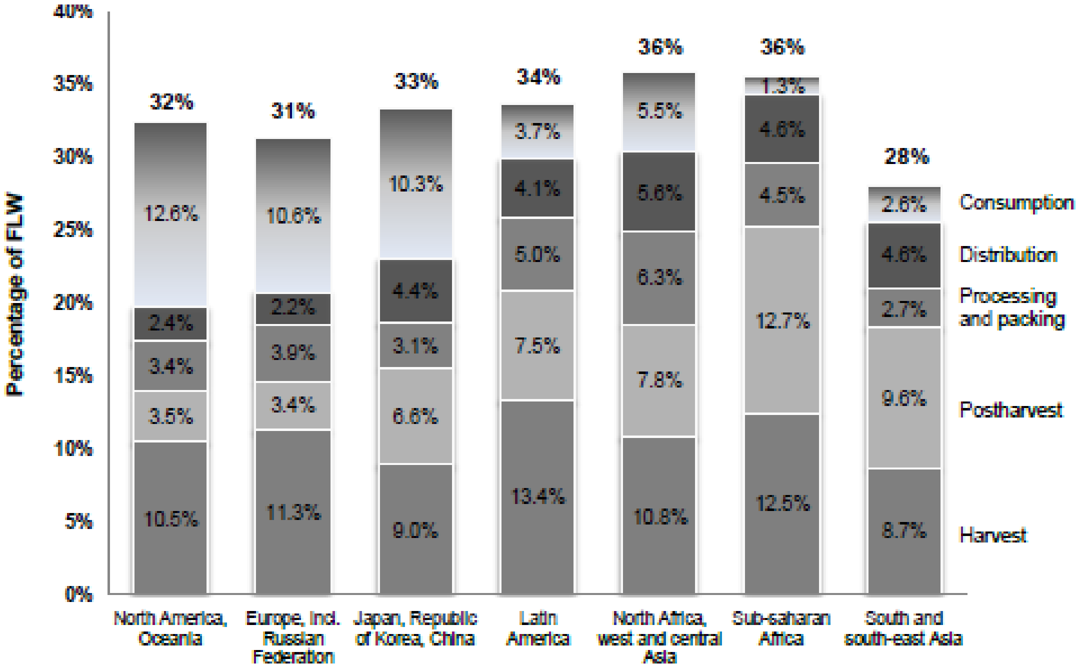
Food waste (FW) refers to “food appropriate for human consumption being discarded or left to spoil at consumer level – regardless of the cause.”

Food quality loss or waste (FQLW) refers to the “decrease of a quality attribute of food (nutrition, aspect, etc.), linked to the degradation of the product, at all stages of the food chain from harvest to consumption.”

Source: HLPE, 2014.

FLW quantities along the food chain are different for various with commodity and for different regions of the world (Gustavsson *et al.* 2014; HLPE, 2014.) (**Figure 9**).

Figure 9 Distribution of FLW along the food chain in the different world regions



Note: The bars represent the percentages lost or wasted at each step of the chain, expressed in percentage of the initial production (edible part originally intended for human consumption).

Source: HLPE, 2014.

Brief description of Food Loss and Waste: Significant FLW occurs on-farm, post-harvest, during transport and distribution, packaging, retailing and consumption (Lipinski *et al.,* 2013). A significant amount of food is lost from the human food supply because of safety and quality considerations. Post-harvest losses may occur because of infestation by pests, microbial spoilage or quality deterioration due to improper handling and storage conditions. Inadequate control of the products' environment and packaging also results in losses of fresh and processed products during transport and distribution. With respect to food safety considerations, there can be safety hazards due to microbial as well as chemical risks (e.g. pesticide residues). Deterioration in food quality due to loss of texture, flavour sensory appeal and nutritional quality occur post-harvest which renders food produce unacceptable to the consumer also contribute to food loss and waste. Loss of quality can occur at all stages of the supply chain and control of the products' environment (e.g. temperature, humidity, atmosphere) and use of appropriate packaging are important to minimize loss of quality and microbial spoilage and maintain nutritional value (Mahajan *et al.*, 2017). A range of preservation processes, such as freezing, drying, fermentation, canning, pasteurization and sterilization may be used to process foods for extending shelf-life (Langelaan, *et al.*, 2013). Where there is processing of produce, there can also be food loss due to under-utilization of edible by-products and side streams of food processing (Augustin *et al.*, 2016). For example, it is estimated that processing of fruits and vegetables results in 25-30 percent waste. These can be used for the recovery of a range of bioactive compounds, thus creating a value-added stream for processing waste that would otherwise be wasted (Sagar *et al.*, 2018). In addition, some products which do not meet cosmetic specifications but are of acceptable eating quality are rejected due to their appearance (de Hooge *et al.*, 2018; 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). For developing countries, food loss usually occurs during production and the post-harvest stage of the supply chain, due to the lack of know-how 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.

However, there is insufficient post-harvest research in the underdeveloped world, as there are insufficient global funding mechanisms for capacity building and knowledge development to minimize food loss and waste in their supply chains (Alamar *et al.,* 2018). Strategies to improve consumer understanding will help facilitate the behavioural change required for consumer acceptance of food technologies and processing interventions aimed at reducing food losses and waste. Education and embedding community perspectives in policies will help people make healthy choices about available sustainable foods (Benyam *et al.,* 2018).

Key points to reduce FLW in SFSs: There are significant challenges to reducing FLW as it is complex issue. The recent HLPE report (2014) suggests that there is a need to:

- Obtain more accurate data on the amount and location of food loss and waste (Schanes *et al.*, 2018);
- Develop strategies that are appropriate for the different levels at which food loss and waste occur;
- Ensure that the appropriate steps are taken by various stakeholders with improved coordination.

Innovation and innovation systems to reduce FLW in SFSs: Greater consumer awareness with involvement of all stakeholders along the supply chain (i.e. producers, distributors, retailers) and standards-setting organizations are necessary for setting appropriate specifications and is a step towards reducing FLW (Mattsson, 2015). There are existing 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 food loss and waste as discussed above, but the implementation of technologies has been difficult. Approaches to reducing FLW has to include all players along the food value chain. It requires education and incentives to change individual and collective behaviors and has to be accompanied by economic incentives (Hertel, 2015). There are many food banks in various countries that re-distribute food to vulnerable communities and have helped make them more food secure. SAVE FOOD (FAO) is an example of a global Initiative on FLW reduction (Michelini *et al.,* 2018).[15]

Local food clusters could increase economies of scale in local production in transport, processing and marketing (Korhonen *et al.*, 2017). The development of regional processing hubs to deal with processing of fresh perishable products into stable ingredients and food products is also a step toward decreasing food loss. A future virtual and physical node in the food value chain (FOODLOSSBANK™) has been proposed to facilitate recovery of food loss for processing into ingredients and products (Petkovic, 2017). The digitalization of the food supply chain with the use of big data and the internet of things will provide new practical insights into existing and emergent food loss and waste scenarios and facilitate interventions to reduce food losses (Irani *et al.*, 2018). Multi-stakeholder perspectives need to be taken into account to develop the innovation systems that are acceptable to all and which address economic, environmental and social impacts of the innovations (Mourad, 2016).

2.5 Contribution of approaches to FSN outcomes and impact

This chapter has stressed the importance of innovation as a process, building on the values and orientations of different approaches. These are heterogeneous in nature, from a stress on technological innovations, to ensuring relevance by being based on local knowledge and experience and addressing multiple benefits beyond purely economic ones.

For innovations to be relevant to securing FSN, they must specifically address the multiple dimensions as outlined in the conceptual framework for achieving FSN (**Figure 6**). These include the overarching principles of SFSs (to improve resource efficiency, strengthen resilience, secure social equity and responsibility, and address ecological footprint) and the evolving pillars of FSN (availability, access, utilization, stability and agency).

For each approach/innovation system reviewed, the following key points emerge as to how each addresses the dimensions of the conceptual framework:

Sustainable Intensification: Sustainable intensification in principle and practice contributes most strongly to the concept of producing more from the same area of land while reducing negative impacts, thus to the dimensions of availability and stability with respect to food security and nutrition and to

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

resource efficiency and resilience within the operational principles of sustainable agriculture. Conservation agriculture, as an integral component of sustainable intensification, has a long history of application, particularly in Latin America. Its innovation systems, working through both social and economic channels thus might merit greater attention, in understanding the adoption of sustainable agriculture approaches.

Organic Agriculture: Organic agriculture contributes to FSN in providing evidence (and incentives for practices) that show that environmentally friendly and economically viable alternatives exist to conventional production, thus stressing stability (with respect to FSN) and resilience and ecological footprints (with respect to SAD). Debates continue and are explored around the yields of organic versus conventional production.

Agroforestry: Agroforestry focuses on the role that trees integrated in agricultural systems can play in avoiding and reversing land degradation and achieving sustainable intensification through enhancing ecosystem service provision. Child nutrition and groundwater recharge at landscape scales in Africa have been found maximum at intermediate levels of tree cover. How trees are used and controlled in agricultural and food systems is bound up with land tenure, gender politics and other social issues that together with a recent paradigm shift towards larger scale and more inclusive approaches has resulted in agroforestry contributing directly to all five pillars of SFS for FSN.

Climate Smart Agriculture: Climate smart agriculture introduces a new element into sustainable agriculture innovation systems, in including (along with productivity and resilience pillars) the aspect of mitigation of greenhouse gases. It thus aspires to address global environmental goals, at the same time as its proponents stress the need to identify suitable and context-specific production technologies and practices. Its strongest links to FSN are on the dimensions of availability and stability, and resilience and environmental footprints (with respect to SAD).

Permaculture: Permaculture, as an alternative agriculture movement, focuses on designing productive systems where structural and functional patterns of nature are the main guiding principles, and where cultural and social values are predominant. It has evolved as an innovation system based on the integration of nature and culture. Its approach contributes substantially to the aspects of food security and nutrition around availability (production of multiple products), access, stability and agency, and to all the operational principles of SAD of improving resource efficiency, strengthening resilience, securing social equity and responsibility, and addressing environmental footprints.

Nutrition sensitive agriculture: Nutrition-sensitive agriculture, as 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" thus primarily contributes to addressing access, availability and utilization (including sanitation and infant and child feeding) aspects of FSN, although not specifically any of the four operational principles of SFSs.

Sustainable food value chains: Sustainable food value chains (SFVC) are 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". As such, SFVC has potential to contribute to the access, stability, and utilization aspects of FSN, and to the resilience, social equity/responsibility and environmental footprint aspects of SAD.

Rights based approaches: Several approaches to addressing FSN are subsumed under rights-based approaches – addressing political, social, economic and cultural rights – including food sovereignty, right to food, food justice and women's empowerment. These contribute substantively to the access and agency aspects of FSN and through the empowerment of women to the aspects of sanitation and infant and child feeding. With respect to SAD, the approach contributes to the social equity/responsibility aspects of SAD.

3 DRIVERS AND CHALLENGES TO INNOVATION FOR SFS

Decisions to innovate are often made in a changing environment, under great uncertainty (Rosenberg, 1994). Identifying the key drivers of and barriers to innovation is thus critical to better understand innovation processes and design policies and programmes that foster innovation (OECD and Eurostat, 2005). The innovative approaches to achieving FSN as described and compared in Chapter 2 focus on different parts of the food system with different emphasis on change to institutions, knowledge and practice (or technology), the relationships amongst these three types of innovation, and the extent to which innovation is internally generated, introduced or adapted. It follows that they interact with key drivers of innovation and key barriers to innovation (see Sections 3.1.1 and 3.1.2) in different ways and ultimately represent alternative strategies for what change is necessary to achieve FSN and how it is best supported. While it is evident that there is considerable overlap amongst the approaches, considered together, they also present alternatives, not all of which are compatible with one another (**Table 3** in Chapter 2). This results in ongoing debates in the scientific literature and political discourse around FSN about whether adopting certain approaches might undermine political, social and ecological drivers that other approaches consider necessary to support development of SFSs (Caron *et al.*, 2018). These debates represent divergent narratives about sustainable innovation, embracing the main drivers of, and barriers to, agroecological and other innovations, as well as the main challenges faced by actors, trying to promote innovative pathways, processes, and systems. Clarifying the nature and extent of these divergent positions and the evidence upon which they rest, is useful in understanding the potential contributions that agroecological and other innovations can make to enhancing FSN, where uncertainties or fundamental disagreements remain and what can be done to remove barriers and enable the changes necessary to achieve FSN.

None of the innovative approaches in Chapter 2 were found to fully address all aspects of developing SFS for FSN. In this chapter, the aim is to clarify the roles different approaches can fulfil in contributing to the five pillars of FSN: availability, access, stability, utilisation and agency; and the extent to which they can co-exist and complement one another to achieve FSN. It documents the drivers and challenges for various innovations through reference to concrete case studies and provides an informed basis for navigating key controversies around their interaction. It also highlights areas of convergence, complementarity, and apparent conflict between agroecological approaches and other approaches to developing SFS for FSN. The appropriateness of innovative practices or technologies are also assessed in the light of their purpose, results, and impacts in specific contexts. For example, in exploring the extent to which agroecology can provide opportunities for addressing climate change (resilience, mitigation, adaptation). The chapter concludes with a summary of the lessons learnt about drivers of innovation and how barriers might be overcome, that help to shape recommendations built on sound science, coupled with local knowledge and experiences in the field, society and industry.

3.1 Drivers of, and barriers to, innovation for FSN

Before exploring their action in specific contexts, through documenting a series of divergent narratives, key drivers of, and barriers to, innovation are briefly outlined in the following two sub-sections. A final section after the narratives draws conclusions relevant to creating an enabling environment that supports innovation capable of achieving FSN.

3.1.1 Drivers of innovation

Innovations in agriculture and food systems have been driven and motivated by a number of factors operating at different scales. Globalization; advances in the generation of, and access to, knowledge and technologies; changing societal demands on food chains and their institutionalization; can all be considered major drivers of innovation. The extent to which these drivers have induced or triggered innovations at different scales has often been associated with changes in agricultural paradigms such as the green revolution, sustainability and biotechnology (e.g. Gijsbers, 2009). These drivers are in turn shaped by local-level factors such as farm size, farmer access to agricultural education and extension, age of the farmer and access to off-farm work opportunities, and markets (Hazell and Wood, 2008; Läpplea *et al.*, 2015). Understanding how such drivers and related factors influence or create new opportunities for innovation in agriculture and food systems are explored in the remainder of this chapter.

3.1.2 Barriers to innovation

The set of factors likely to hamper or slow-down the innovation process and restrict access to innovation (OECD and Eurostat, 2005; World Bank, 2010; FAO, COAG/2016/6) can be grouped as followed and include:

- ***economic factors***, such as: high costs, uncertainty of results or excessive perceived risks associated with innovation, lack of funds within or outside the enterprise;
- ***knowledge factors***, such as: lack of knowledge or of skilled staff, limited innovation potential, lack of information on existing or new technologies, lack of information on markets and demand;
- ***market factors***, such as: uncertain demand for innovative products or services, high entry costs when a potential market is dominated by established enterprises or becomes oligopolistic;
- ***institutional factors*** (internal or external), such as: lack of partnerships with other enterprises, organizational rigidities in the enterprise; lack of infrastructure and resources (human and financial) at the country level; inappropriate legal framework (legislation, regulations, standards, taxes and subsidies, property rights); weak governance.
- ***social and cultural factors***, such as: resource endowment, access to knowledge and information platforms, social capital, exposure, cultural practices and food preferences.

It is evident that the approaches to innovation outlined in Chapter 2 differ in their emphasis with respect of these factors. For example, rights based approaches focus on enabling institutional change whereas sustainable food value chains emphasise market factors. Some approaches, including agroecology, promote specific ways of addressing knowledge constraints to innovation through reconfiguring the relationship between local knowledge and global science and promoting horizontal, farmer to farmer, knowledge sharing (Rosset *et al.*, 2011). Clearly, the action of these groups of factors interact, for example, social and cultural factors influence access to knowledge. In any specific context the relative importance of these barriers to innovation may vary, making different approaches to FSN more or less likely to be able to overcome them. In general, there has been more emphasis in predominant approaches to agricultural improvement in the past on economic, market and some knowledge barriers to innovation creating an urgent need in many contexts to address social, cultural and institutional factors (Gomiero *et al.*, 2011). This is consistent with the trend in the evolution of many approaches and of agroecology in particular, to embrace more holistic visions of whole food systems (Wezel and Soldat, 2009).

3.2 Diverging narratives

While there is a global consensus emerging around the need to transform agriculture and food systems through an "Evergreen Revolution" (Swaminathan, 2000; Fresco, 2015; HLPE, 2016, 2017a, 2017c) that is sustainable and equitable as well as productive, many states and non-state stakeholders have different views about the innovative approaches that can be used to do so (FAO, 2011a; Caron *et al.,* 2014; Tittonell, 2014; Pimbert, 2015; HLPE, 2016; IPES-Food, 2016; FAO, 2017).

Some approaches (such as "sustainable intensification") focus on technical solutions that reduce yield gaps. Some (like "conservation agriculture") adopt a field level approach. Some (like "climate-smart agriculture") try to accommodate social and environmental concerns in current food systems and open the door to all technologies and practices, including biotechnologies. Others consider the development of sustainable food manufacturing factories. A clear distinction between practical and technical solutions and their ideological or political background might help to identify the synergies and overlaps between these different innovative approaches in terms of practical action at the farm level (HLPE, 2016). Previous HLPE reports have also considered divergent views and framed controversial issues in relation to nutrition, small-scale agriculture and food waste, upon which recommendations for action emerge (HLPE 2014, 2016, 2017) . The following sections build on these previous HLPE reports and specifically recognize the elements of selected controversies which arise from the different contexts in which agroecological approaches and other innovations may be applied for enhancing FSN.

The following six subsections explore key divergent narratives that frame the current discourse on how to achieve FSN. Agroecology can be seen as a co-evolution of political and scientific discourses and agendas and, as a result, it has an important role in achieving SFS beyond the specifics of current agroecological practices, through exemplifying a transdisciplinary approach aiming to address the whole food system. Other approaches (**Table 3**, Chapter 2) make distinct contributions to SFS. Both agroecological and other approaches have to be appropriately designed and implemented at scale with an FSN perspective for SFS to be realized. The most appropriate technology to deploy in any specific case may be context-specific, although there is often a lack of consensus about the appropriateness of the technologies and approaches recommended for adoption generally and in given contexts. It is important to explore the controversies that underpin these differences and seek to build consensus where possible about the role of agroecology and other innovations for achieving FSN and to clarify disagreement and knowledge gaps where no consensus exists. This process will clarify how and when the specific principles within different approaches (**Figure 6**, Chapter 2) can most appropriately be used. It is anticipated that employing a transparent process to uncover the basis for the following divergent narratives will clarify (i) what, if anything, makes agroecology different from the application of other innovations, (ii) the extent to which agroecology can co-exist with other approaches and (iii) the challenge for impacting at scale and for mobilizing appropriate technology based on sound scientific insights about sustainable agriculture.

3.2.1 Scale: can innovation approaches embrace both small- and large-scale operations?

The relative contribution to FSN and SFSs of small versus large farms and how each is supported in different food systems is an important consideration for policy makers.

Issues of scale and innovation systems: issues of scale are often at the heart of divergent narratives about the future of agriculture. With respect to the approaches profiled here, it is possible to characterize how each interfaces with issues of farm size and scale on the basis of their stated principles (**Table 4**).

Table 4 Scale comparisons of approaches to innovation based on princples of each approach as documented in Chapter 2

	Favours small-scale farm sizes	Scale neutral	Favours larger farm sizes
Agroecology	+		
Sustainable intensification		+	+*
Agroforestry	+#	+	
Organic agriculture	+	+	
Climate-smart agriculture		+	
Sustainable food value chains		+	+
Permaculture	+		
Nutrition-sensitive agriculture		+	
Rights-based approaches	+		

(*Promotes introduction of technology, but recognises that this may have impacts on equity, with larger farms often advantaged as noted in Royal Society, 2009, among others; #scale neutral in concept but a lot of tropical agroforestry research and development has focused on smallholders (Lasco *et al.*, 2014)

Revisiting economies of scale: An older but often repeated narrative in agricultural development has been that many of the farms in developing countries are too small to justify investment; 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 US 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; and, the large-scale production systems favoured by the economy of scale argument often involve negative externalities from environmental damage and impacts on rural communities that are not included (Duffy, 2009). An inverse relationship between farm sizes and measured productivity has been documented repeatedly; small farms have been 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. For example, the conventional model of increasing land and labor productivity may not be applicable in areas of the world with high population pressures, such as India and many parts of sub Saharan Africa (Dorin, 2017).

Simple yield measurements in small, diverse farming systems may not adequately reflect actual production. The "polycultures" that characterize many smallholder farms in parts of Africa, Latin

America and Asia – with grains, fruit, vegetables, animal fodder and livestock cultivated in the same field – generally out-produce the yields of single crops grown over the same area, in terms of harvestable products per unit area, even if the yield of any one crop is below that of monocultures on larger farms. Yield advantages have been estimated from 20 to 60 percent higher, in part attributed to the fact that polycultures may effectively suppress weeds by occupying all available growing space, reduce losses due to pests and diseases through fostering multiple species, and make more efficient use of water and light (Francis, 1986 Badgley *et al.* 2007; Cardinale *et al.* 2007; Prieto *et al.* 2015) While 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) the yield gap ranges from 8 percent to 20 percent, with two global reviews finding that diversified systems outperformed conventional systems in the developing country context by as much as 80 percent (Badgley *et al.* 2007; Pretty *et al.* 2006). Given the limited amount of public investment in agroecological approaches, with estimates between 1 and 1.5 percent of total agricultural and aid budgets (Delonge *et al.* 2016; Pimbert and Moeller 2018) these findings suggest high potential for addressing yield gaps with greater investment.

Farm size and scale and contributions to FSN: It is important to understand, at this point in time, what kinds of farm operation scales are currently ‘”feeding the world”: – not just with calories, but with diverse diets that contribute nutrients, fibre and other crucial features of a healthy diet. Several recent analyses provide a useful typology to link farm sizes with salient features of food systems around the world, distinguishing between traditional food systems, mixed food systems and ”modern” food systems (**Table 5**).

Table 5 Key features of recent food systems typologies, which serve to distinguish elements across a complex continuum from traditional to ‘modern’.

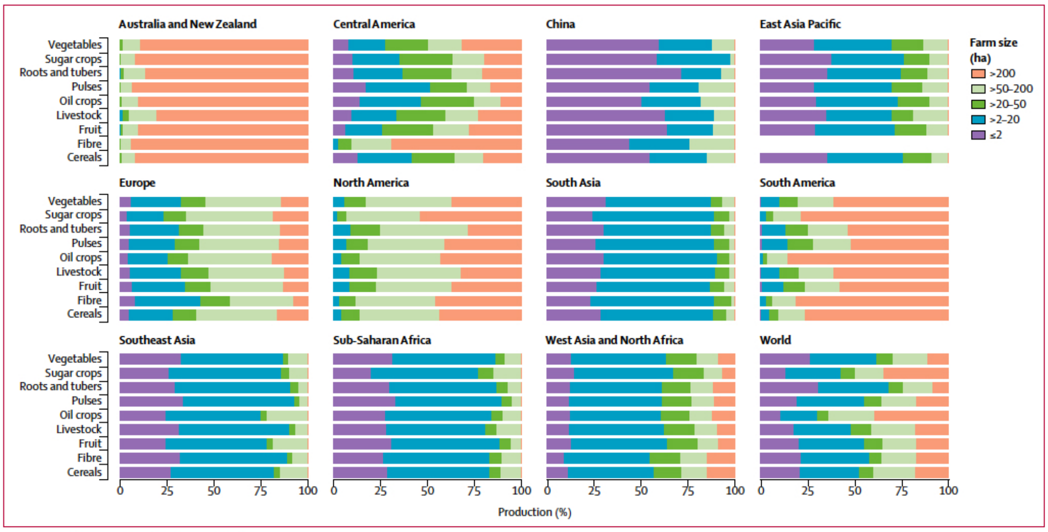
Food system feature	“Traditional” food systems	Intermediate/mixed food systems	“Modern” food systems*
Estimated number of people in system	~1 billion	~4 billion	~2 billion
Principal employment in food sector	In food production	In food production	In food processing, packaging and retail
Food production system	Diverse, mixed production system (crops and animal production) by smallholders; local and seasonal production with varied productivity and diverse benefits; low input farming systems. Food systems are the main source of energy.	Combination of diverse, mixed production system and specialised operations with a certain degree of inputs, including fossil fuels, by both local smallholder farmers and larger farms often further away. Less dependence on seasonal foods.	Few crops dominate (i.e. largely monoculture); specialization and high productivity; high external inputs, including fossil fuels. Food production consumes more energy than it delivers. Overall, the system produces a wide array of foods that are available globally.
Typical farm	Family-based, small to moderate	Combination of smallholder farms and larger farms / fishery operations	Industrial, larger than in a traditional setting

Source: adapted by Pengue and Gemmill-Herren (2018) from Ericksen (2008), UNEP (2016a) and HLPE (2017).

As per this typology, the small to moderate sized farms, with diverse mixed production systems tend to be found in traditional and mixed food systems, while larger industrial farms are part of modern food systems (with no clear-cut boundaries between these). Approximately 5 billion people are part of traditional and mixed systems, while around 2 billion are part of the “modern” or more industrialized systems.

Herrero *et al.* (2017) provide a breakdown of global agricultural production and of nutrient production, by farm size (**Figure 10**). The report finds that globally, small and medium farms (below 50 ha) produce 51–77 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.

Figure 10 Production of key food groups by farm size



Production of key food groups by farm size

Source: Herrero *et al.* (2017).

Herrero *et al.* (2017) also found that the diversity of agricultural and nutrient production diminished as farm size increased, but regardless of farm size, it is shown that 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 FSN, but very small, small and medium-sized farms (found mostly in traditional and mixed food systems) produce more food and nutrients in the most populous (and food insecure) regions of the world than large farms in modern food systems(Graub *et al.* 2016). Maintaining diverse agricultural landscapes, globally, is linked to producing diverse nutrients in viable, sustainable landscapes (Johns *et al.* 2013; Jones *et al.* 2014; Powell *et al.* 2015; Pelligrini and Tasciotti, 2014).

Farm scale and ecological approaches to food production: Farm scale has strong links to ecological approaches to food production, as embraced by agroecology. Closely linked to the capacity of farming systems to work effectively with natural processes, such as recycling of biomass and provision of pest control and pollination services, is the scale and size of farms, as well as the diversity of the landscape. For example, smallholder farmers, cultivating fields of less than two hectares, have been shown to be able to increase yield gaps by a median of 24 percent by promoting greater visitation of pollinators to their crops; their already high levels of diversity support populations of pollinators that can be enhanced by relatively simple measures. Notably these are options that are not so readily available to larger-scale farmers (Garibaldi *et al.,* 2016). Ecological pest control works to restore the balances between pests and the agroecosystem through the use of cultural techniques, promotion of on-farm diversity and choice of appropriate varieties and introduction of natural enemies (see **Box 2**). These measures that require on-farm intricate knowledge can most effectively be implemented at relatively smaller scales of farming operations. Sustaining soil health and fertility, under agroecological approaches that revolve around measures through crop rotation, cover crops and application of compost and organic manure, are more operational when farm sizes are relatively small.

Farm scale and social equity and well-being for farm communities: Farm size had an influence on social equity and community well-being (Crowley and Roscigno 2004; Deller 2003; Donham *et al.* 2007; Foltz and Zueli 2005; Jackson-Smith and Gillespie 2005; Lyson *et al*., 2001)**.**The rationale for focusing on and promoting smallholders recognizes that these farming systems are key to addressing equity, poverty, FSN, employment and sustainable management of natural resources (Gollin, 2018). 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 related to scale (Pretty and Barucha, 2014). The type of socio-economic organization associated with scale, such as absentee land owners, contract farming, reliance on farm managers rather than owner-operators, are factors that place communities at risk (Crowley and Roscigno 2004; Lyson and Welsh 2005; Jackson-Smith and Gillespie 2005). A community characterized by small family farms, as compared to one dominated by large corporate enterprises, was found to have a better quality of life, superior public services and facilities, more parks, shops and retail trade, twice the number of organizations for civic and social improvement, and better participation by the public. The small farm community was seen as a better place to live because: "small farms offered the opportunity for 'attachment' to local culture and care for the surrounding land". These findings have been confirmed in other contexts: social connectedness, trust and participation in community life were greater where farm scale was smaller, with different types of social organizations associated with scale (Crowley and Roscigno 2004; Donham *et al.* 2007; Lobao, 1990; Lyson *et al.* 2001).

Farm size and addressing nutrition

The poor and those with low social status, especially vulnerable groups including young children, pregnant and lactating women, the sick and the elderly are most at risk of inadequate FSN. 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 the food insecure and malnourished, with 75 percent of the world's poorest households living in rural areas and depending on agriculture (FAO, 2015, 2017b). Numerous studies have found a positive relationship between diversified farming systems and human nutritional outcomes for smallholder farms (Bellon *et al.,* 2016; Demeke *et al.,* 2017; Jones *et al.,* 2014; Powell *et al.,* 2015). Species richness, one measure of biodiversity, has been found to be highly correlated with micronutrient adequacy in human diets (Lachat *et al.,* 2018). Wild biodiversity on or near farms also plays an important role in many rural household diets (Powell *et al.,* 2015). In some cases, market access, remittances, women's control of income, ethnic food preferences or other political, economic socio-cultural 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). However, unequal distribution of diverse foods within households based on age, gender and other factors can also occur even when households are food secure (Leroy *et al.,* 2008; Haddad *et al.,* 1996). Efforts to foster agricultural biodiversity and diet diversity on smallholder farms must take these socio-cultural and economic factors into account (Jones *et al.,* 2014; Keding *et al.,* 2013; Ng'endo *et al.,* 2016).

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). Large-scale land acquisition can push out smallholders, leaving them vulnerable to food insecurity (Nyantakyi-Frimpong, 2017). Farmworkers' and poorer farmers' FSN status can be worsened when intensification occurs, along with the environmental resources on which they depend, such as forests and water supplies (Powell *et al.,* 2015; Rasmussen *et al.,* 2018).

Farm size and innovation: Proponents of sustainable intensification in agriculture note that farm size must be a consideration in how technologies are transferred and the ability of various farmers to adopt technologies and manage risks of trying new approaches. Larger farmers benefit from new technologies and this may put pressures on smaller farmers, who may risk being forced out of farming and becoming landless (Royal Society, 2009). In some countries large-scale farmers also receive disproportionate support through subsidies and other state programs (Bruckner 2016; Dorward and Chirwa). Sometimes, processes of technology transfer can serve to exacerbate rather than alleviate poverty (Adesina, 2009).

Farm size 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 can create 'international poverty traps' in such cases in which the poor are unable to escape poverty (UNCTAD 2013; 2002). 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.

Farm size as a focus of policy: Farm size remains a critical issue in policy as many countries pursue policies intended to promote the size of individual farms. Some, under the belief that larger farms have economies of scale and contribute more to economic growth, seek to promote consolidation and land markets, through land titling and measures such as "growth corridors". Other countries seek to limit consolidation, through restrictions on land markets and farm sizes (Gollin, 2018). The question is "In what ways should governments address issues of farm size to best secure FSN for their populations?" From the evidence presented here, a focus on the small and medium-sized farms that currently provide the majority of the world's nutrition, building on the advantages of their small scale and inherent diversity through agroecological approaches, would be a sound investment.

Scaling out, supporting networks of farmers, scientists and civil society groups to promote the sharing and co-creation of knowledge to manage these diverse, complex ecosystems across and between farm and research communities), thus takes the place of "scaling up" or favouring large-scale enterprises (Brescia 2017; Holt-Gimenez 2006; Khadse *et al.* 2018; Mier y Terán Giménez Cacho *et al.*, 2018; Nicholls and Altieri 2018; Nyantakyi-Frimpong *et al.* 2017).

At the same time, 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 (Leibman and Schulte 2015, Helmers *et al.* 2012, Zhou *et al.*, 2014). Thus the scale question may ultimately be more of a diversification question, applicable at multiple scales.

3.2.2 Can agroecology feed the world?

Some people think that you 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 can feed the world (Muller *et al.,* 2017).The modelling of food requirements and future supply chains for a growing population sets the scene for how much food needs to be produced in the future. Against these estimates, further modelling may be required to determine the extent to which agroecology and other innovations can contribute to FSN. However, the different assumptions and conditions used within such models need to be transparent.

An increase in agricultural production would be required to feed the global population, estimated to reach 9.7 billion by 2050 unless major changes are made in global food systems (Berners-Lee, *et al.* 2018). FAO estimates that to meet a growing demand for food, global agricultural production will have to increase by almost 50 percent between 2012 and 2050 (FAO, 2017); however this estimate has changed (and decreased) considerably over the last decade, as assumptions in earlier estimates have been challenged; one very recent estimate is that a 19 percent increase will be needed if global food systems follow a "business as usual trajectory (Berners-Lee, *et al.,* 2018). Estimates vary depending on whether food waste and agricultural production for animal feed, biofuels, shifting diets and non-food uses are considered in the modelling (Berners-Lee, *et al.* 2018, Keating *et al.,* 2014). Agricultural production will also need to prepare for the increase in the urban population and consider economic, ecological and social concerns of conventional industrial agriculture (Kahane *et al.,* 2013). The need for such an increase in production is contested, with some estimates indicating 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). Increasing production alone will not be sufficient to tackle hunger and other issues such as food availability, access, utilization and stability have to be taken into account (FAO, 2018). Still 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, 2016, 2017b). There is a growing consensus that improving FSN needs to simultaneously address the production gap, improving access to food, reducing food losses and waste, and facilitating the agency of communities to enhance FSN. Also, changing consumption patterns is seen as a necessary pathway. In this context, it is now discussed if implementation of agroecological approaches could feed the world.

Box 10 Comparison of industrial vs diversified agroecological farming

SPECIALIZED INDUSTRIAL AGRICULTURE	DIVERSIFIED AGROECOLOGICAL FARMING
DEFINITIONS	
Specialization refers to a socio-economic paradigm whereby producers specialize in the production of a single item (or few items) that they are most efficient at producing, or of a single stage of that item's production. Industrial agriculture refers to modes of farming that are analogous to industrial processes in their scale and task segregation, and seek to derive productivity gains from specialization (see above) and intensification of production. At various points in the report, 'industrial agriculture' will be used as short-hand to refer to a model which entails and is based around highly-specialized production.	Diversification refers to maintaining multiple sources of production, and varying what is produced across farming landscapes and over time. Agroecology is understood here as "the science of applying ecological concepts and principles to the design and management of sustainable food systems" (Gliessman, 2007). It encompasses various approaches to maximise biodiversity and stimulate interactions between different plants and species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems and secure livelihoods. It also represents a social movement; this usage will be specified where relevant.
KEY CHARACTERISTICS	
Crop monocultures (or production of a handful of select crops) at the level of farms or landscapes; Concentrated Animal Feeding Operations (CAFOs).	Temporal diversification (e.g. crop rotation) and spatial diversification (e.g. intercropping; mixed farming); diversification employed at various levels, including plot, farm and landscape.
Use of genetically uniform varieties or breeds selected mainly for high productivity, wide adaptability to favourable environments, and ability to respond to chemical inputs.	Use of wide range of species and less uniform, locally-adapted varieties/breeds, based on multiple uses (including traditional uses), cultural preferences, taste, productivity and other criteria.
Vertical and horizontal segregation of product chains, e.g. animal feed production and animal rearing in separate farms, value chains and regions.	Natural synergies emphasized and production types integrated (e.g. mixed crop-livestock-tree farming systems and landscapes).
Highly mechanized, labour-saving production systems.	More labour-intensive systems.
Maximization of yield/economic returns from a single product or limited number of products.	Maximization of multiple outputs.
Intensive use of external inputs, e.g. fossil fuel, chemical fertiliser, pesticides and antibiotics.	Low external inputs; recycling of waste within full nutrient cycling and circular economy approaches.
Production of large volumes of homogenous products for national and international markets, typically within long value chains.	Production of a wide range of less homogeneous products often destined for short value chains; multiple sources of production, income and livelihood.

Source: IPES-Food 2016.

The debate as to whether or not agroecology can feed the world may be based on a false controversy, or at least, an incongruity since despite high levels of production, food insecurity and malnutrition persist (Chappell, 2018). The problem of hunger and famine is not primarily a matter of food production, but one of power and access to food (Smith and Haddad, 2015). There are structural issues such as access to land, inflation, political instability and wealth distribution influencing FSN. The ground breaking works of Amartya Sen, Nobel laureate in economics, established the relationship of entitlement and famine (Sen, 1981). In fact, many countries such as Brazil, China and South Africa, amongst others, are food exporters but yet have part of the population vulnerable to food insecurity

(FAO *et al.*, 2017). Addressing food insecurity and malnutrition within SFSs will thus require agroecological approaches to be embedded in a food system intervention that addresses these social inequalities (Kanter *et al.*, 2015; Massett *et al.*, 2011). ‘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 2017). The kcal energy requirements do 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 2017). Further, even if sufficient nutritious food is produced, without addressing underlying power inequalities, food insecurity and malnutrition will persist. A systems-based approach which links agricultural productivity, food safety, food processing, sustainable supply chains and health of populations considering global and industry megatrends is required for FSN (Cole *et al.*, 2018).

Box 11 Food security estimates based on calorie requirement

Food security estimates have historically been based on the total calorie requirements. The estimates for food demand vary between $8.9x10^{15}$ – $12.3x10^{15}$ kcal/year in 2030, with estimates depending on assumptions around consumption patterns, biofuel and food waste.

Source: Keating and Carberry, 2010; Alexandratos and Bruinsma, 2012; Valin, 2014.

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). Despite there being sufficient food produced on a global scale, around 820 million people are still hungry (FAO/IFAD/UNICEF/WFP/WHO, 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 2017). Child malnutrition is concentrated in Asia and Africa: more than half of all overweight children and more than half of all stunted children under five years live in Asia and one quarter of overweight children and more than one-third of all stunted children under five years live in Africa (UNICEF *et al.,* 2017). There has been no progress to stem the rate of overweight people in more than 15 years, and child stunting rates are declining slowly or in some cases not at all (UNICEF *et al.,* 2017). Child stunting increases the risk of impaired cognitive ability, infection and mortality.

While dietary intake is an important immediate determinant of FSN, the main underlying drivers are not production, but rather income, conflict, inequality at multiple scales (e.g. gender or racial inequality), environmental conditions (e.g. exposure to pathogens, climate), health care, consumption and childcare practices (Smith and Haddad, 2015; FAO, 2017; Sen, 1982). The quality of care practices, including child feeding and support for women during pregnancy and lactation, are crucial underlying determinants of child nutrition (Black *et al.,* 2013). The ability of a government to be responsive to people’s needs is another key underlying determinant of FSN, by ensuring that there are not conflicts, that people have adequate health services, education, income and opportunities to produce, access and afford food, and democratic accountability to address food insecurity and malnutrition-related drivers as they arise (Smith and Haddad, 2015; Rico *et al.,* 2011). A recent study found that safe water access, sanitation, women’s education, gender equality, and the quantity and quality of food available in countries have been key drivers of past reductions in stunting between 1970 and 2012 (Smith and Haddad, 2015). Food quantity only accounted for an estimated 18 percent of reduced stunting, food quality contributed 15 percent and women’s education contributed 22 percent to the total reduction in stunting (Smith and Haddad, 2015).

The perspective that agroecology cannot have a major contribution to feeding the world may also be based on an incorrect assumption, i.e. that agricultural systems based on agroecological methods are less efficient in terms of food production. Several recent reviews suggest that agroecological systems can be as or more productive than conventional or industrial agricultural models, (Pretty *et al.* 2003; De Schutter 2011, 2012; d’Annolfo *et al.*, 2017). Another relevant aspect is that much of the private and public investments in agricultural research in the last 50–60 years were primarily based on “Green revolution” technologies which included pesticide use, chemical fertilizers, and machinery, and more recently on genetically modified organisms (Vanloqueren and Baret, 2009; Miles *et al.*, 2017; De

Longe *et al.*, 2016, Pimbert & Moeller 2018). In addition, the majority of teaching and research institutions, and extension services, were oriented to industrial agriculture rather than ecologically sound technologies. Typical education programmes were mostly oriented towards single solution problem solving in conventional agriculture but there is now a growing number of education programmes that bring more holistic approaches and experiential learning into focus (Francis *et al.*, 2017, Francis *et al.* 2017). Therefore, comparisons between agroecological approaches and conventional agriculture can be biased, depending on the narratives and education or training inolved. It has to be recognized that limited funding for agroecological approaches is a fact that needs to be considered when comparing advancement of the agroecology field in comparison to industrial agricultural systems (Delonge *et al.* 2016; Pimbert and Moeller 2018)

In many parts of the world, "industrial" agriculture with its use of high chemical, fossil fuel and resource inputs has resulted in increased agricultural productivity at the expense of loss of biodiversity, land degradation, and major environmental and social impacts (Kremen and Miles, 2012). Overuse of chemical inputs contributes in some instances to loss of soil fertility and biodiversity, and chemical contamination of the water supply and reduced environmental sustainability, with negative knock-on effects on human health. Some have suggested that industrial agriculture is not sustainable (Mahon *et al.,* 2017). For example, industrial large-scale agriculture has been associated with declining biodiversity and habitat loss as seen in the impact of large-scale agro-industrial Ethiopian sugar-cane plantations on species diversity (Degefa and Saito, 2017).

Evidence to date is that agroecological approaches have an important role in securing sustainable diets now and in the future (IPES-Food 2016; De Schutter 2011, 2012). The move towards a more environmentally-friendly and less resources exploiting production system, that also better considers rural peoples' needs, and with the use of agroecological practices, will serve to advance the global food system to achieve FSN (DeLonge *et al.,* 2016). Agroecological approaches embrace diversified farming systems, defined as "farming practices and landscapes that intentionally include functional biodiversity at multiple spatial and/or temporal scales in order to maintain ecosystem services that provide critical inputs to agriculture, such as soil fertility, pest and disease control, water use efficiency, and pollination" (Kremen *et al.,* 2012). Agricultural systems with increasing crop diversity and livestock production diversity with grazing that have many crop and grassland types and small-sized fields improve pollination success of crops, promote pollinator diversity, and is a strategy for enhancing sustainable food production (Kovacs-Hostyanszki *et al.,* 2017, Garibaldi *et al.*, 2017).

Agroecological approaches aim to limit use of synthetic inputs (e.g chemical pesticides and fertilizers; see Chapter 1). To give just one example here, exploiting emerging microbiome approaches, such as manipulating the plant microbiome (i.e. microbiota associated with root, stem, leaves, flowers and seeds) and use of microbial products (e.g. as biofertilizers and biopesticides) have potential to improve resource use efficiency, decrease plant diseases and contribute to increased farm productivity in an environmentally sustainable way (Singh *et al.,* 2018). Plant growth promoting microbes and mycorrhizal fungi may be used to enhance sustainable agricultural production, with potential in future to feed the world with the available resources (Kumar and Verma, 2018). A strategy to improve sustainability might be achieved by de-intensifying high resource input systems but increasing inputs in systems with large yield and efficiency gaps (Struik and Kuyper, 2017). Agroecology is not prescriptive on quantities and types of inputs, rather on goals to substitute ecosystem services to the extent possible.

For example, it can not be clearly stated whether or not any specific farming systems is or is not agroecological, although the more fully that the agroecological principles outlined in Chapter 2 are applied then the more agroecological the system. There is much work going on this world-wide, but there is not yet a commonly accepted agreement on thresholds for what distinguishes an agroecological system. Among the questions that remain are:

- Do all practices on a farm need to be 100 percent agroecological?
- Need they be applied across the entire farm area?
- How much chemical fertilizer use is still agroecological, or not at all?
- Can pesticides or herbicides be used, and in which cases, so that they remain in agreement with agroecological principles?
- Is any type, or which type, of genetically modified crops acceptable with an agroecological approach?

Several reviews suggest that agroecology can make a large contribution to feeding the world. For example, Pretty *et al.* (2003) and De Schutter (2011, 2012) summarized many examples from tropical and subtropical countries with significant yield increases associated with agroecological practices. 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) show in their recent meta-analysis that adopting agroecological practices increases yield in 61 percent of the cases they analysed, for 20 percent it decreased, and the rest there was no change, while farm profitability was increased in 66 percent of cases. It remains unclear how representative the cases so far documented are of agriculture globally and which aspects of the agroecological approaches adopted were responsible for yield and profit improvements.

Numerous studies have found positive relationships between diversified farming systems (a key principle of agroecology), household dietary diversity and nutrition (Carletto *et al.* 2015; Kumar *et al.* 2015; Jones *et al.* 2014; Oyarzun *et al.* 2013; Olney *et al.* 2015; Shively and Sununtnasik 2015; Talukder *et al.* 2000). Supporting diversified agroecological systems alone, however, is usually not adequate to address FSN, but rather such interventions are done in concert with farmer participatory research, nutrition education, efforts to address social inequalities and other public policies (Bezner Kerr *et al.* 2010; Masset *et al.* 2012; Talukder *et al.* 2000; Wittman and Blesh 2017). Given the paucity of investment in agroecology research and implementation (Delonge *et al.* 2016; Pimbert and Moeller 2018), these findings point to its potential to address FSN, through supporting SFSs.

While there is evidence of the potential of agroecology, further research and investment in diversified agroecological systems are needed, including support of education, assessment and the support of networks and civil society groups which train and support groups using agroecology.

3.2.3 Are global science and local knowledge opposed in agroecological thinking and practice?

Agroecology has been described as a science, practice and movement above. Each of these depends on knowledge, accumulates knowledge and uses that knowledge. However, the knowledge bases in each case are not always mutually accessible, trusted and understood. Two examples of polarised views or positions[16] illustrate this:

- That the technologies of conventional or industrial agriculture are the products of science so science and scientists must be anti-agroecology.
- That traditional or indigenous knowledge and practices are unquestionably sustainable and hence worth using elsewhere.

The first of these positions ignores the possibility of science being used in support of agroecology, communities and local efforts. The second position ignores the proven cases of indigenous practices leading to degradation and the fact that traditional knowledge might not provide insights for new problems and contexts. The respective roles of global science and local knowledge in all aspects of agroecology needs clarifying and communicating.

The scientific method, whether applied in social or natural sciences, should provide data and evidence that is open, repeatable, unbiased and objective. However, every scientific endeavour takes place within the researcher's conceptual framework. If this is explicit, documented and shared it is open for critique and bounds what can be expected from the data. If some of the researchers assumptions and judgements remain implicit, as is often the case, then limits to data and their interpretation may be less clear. In either case the conceptual framework sets the way data collection is designed and data is interpreted. At the same time, people engaged in any activity are subject to biases, prejudice and blind spots, and this happens in agriculture as much as anywhere, influencing what they look at and what they see (Chambers, 2017). Thus the notion that science and scientific knowledge are neutral and uninfluenced by human behaviour is not viable. Results that are clear to one group are contested by another, particularly in a contentious field such as agroecology. Hence there is value in understanding the connections between science and other aspects of agroecology and seeking bridges to connect them.

Scientific knowledge has long been associated with the machinery of state (Chambers, 1980) while agroecology has, until recently, been distinctly a non-state sector. In contrast, local knowledge is associated with the roots of agroecology. An example is given in Astier *et al.* (2017) who document the early work in Mexico. However, it is also clear that local knowledge has long been part of formal

[16] These were observed repeatedly during contributions to the FAO Second International Symposium on Agroecology, 3–5 April 2018 http://www.fao.org/about/meetings/second-international-agroecology-symposium/en/

research in agroecology and that some of the mutual criticism of the two domains do not stand up to careful examination (Agrawal, 1995). The two domains of local and scientific knowledge can also be seen as two different views of the same systems and processes, with one providing depth relevant to specific contexts and the other providing generally applicable concepts and principles (Vandermeer and Perfecto, 2013). A powerful example of the way the two can be brought together is provided by the Agroecological Knowledge Toolkit – AKT (**Box 12**; Dixon *et al.,* 2001).

Box 12 The Agroecological Knowledge Toolkit[17]

This is a suite of field and analytical tools for collecting local knowledge about agroecosystems and assembling it into a coherent understanding of cause–effect relationships within the system (Sinclair and Walker, 1998; Walker and Sinclair, 1998). It is built on local knowledge but uses the principles of the scientific method to generate insights that are robust, repeatable and verifiable (Sinclair and Walker, 1999). It has been used in many different agroecological and cultural contexts across Africa (Smith Dumont *et al.*, in press; 2018; 2014), Asia (Thapa *et al.*, 1997) and Latin America (Cerdan *et al.*, 2012) and resulted in the development of knowledge based systems that combine global scientific and local knowledge that help farmers to make informed decisions about practices (Thorne *et al.*, 1999).

Mutual distrust of knowledge bases by groups from different domains is not limited to agroecology. Cash *et al.,* (2003) developed the salience-credibility-legitimacy framework for describing the conditions under which scientific results and knowledge can influence policy and practice, pointing out that conventional institutions only value credibility when assessing research. Saliency addresses relevance to the decision or policy, credibility focuses on technical adequacy in handling of evidence and legitimacy is concerned with being fair, unbiased, and respectful of all stakeholders. The concepts of boundary work and boundary objects are important. They provide mutually accessible and valued information products that are the basis for communication and negotiation between actors in different domains (Clark *et al.,* 2016).

Box 13 Boundary work and boundary objects

Boundary work addresses tensions that occur between communities with different views about what is considered reliable and useful knowledge. Boundary objects are defined as collaborative products such as reports, models, maps, or standards that "are both adaptable to different viewpoints and robust enough to maintain identity across them".

Source: (Clark *et al.,* 2016).

[17] http://akt.bangor.ac.uk/

Table 6 Formal and informal elements of agroecological science, practice and movement

	Practice	Science/Knowledge	Movement
Informal	1. Indigenous and traditional practices	2. Local knowledge	3. Farmer and activist organizations
Formal	4. Designed systems	5. Scientific knowledge	6. FAO

The boundaries that need spanning in agroecology are the connections amongst the cells as defined by the categories in **Table 6**. The columns are the three dimensions of agroecology covered in Chapter 1 (science, practice and movement). The rows are described as:

- Informal: used when the process is spontaneous, often undocumented, often without planned structures and strategies, emerging from community and individual effort.
- Formal: used when the process is planned, organised, documented, implemented by identifiable institutions.

The distinctions and overlaps between formal (or scientific) and informal (or local, traditional) knowledge, described above, have parallels when we consider the practice and movement dimensions of agroecology and these lead to similar feelings of distrust or conflict, some described by Wezel *et al.* (2009). It is easy to find fault with actions or people working in one cell of Table 5 from the perspective of any other cell. Boundary work is needed not just between local and scientific knowledge but between any of these cells. Examples of this can be found in agroecology and include:

- Co-learning principles of soils and soil management though merging local and scientific knowledge using InPaC-S (Participatory Knowledge Integration on Indicators of Soil Quality) (Barrios *et al.*, 2012). The approach has now been extended to include participatory design of soil management experiments. Spans boundaries between cells 2 and 5 of Table 5.
- Structured stakeholder engagement to identify locally relevant options using local knowledge (Smith-Dumont *et al.,* 2017). The approach uses local knowledge in a formal science framework. Spans boundaries between cells 1, 2, 4 and 5 of **Table 6**.
- Community environmental monitoring (Conrad and Hilchey, 2011). The approach engages local communities in monitoring their environment to provide evidence to support advocacy. Spans boundaries between cells 2, 3, 4 and 5 of **Table 6**.

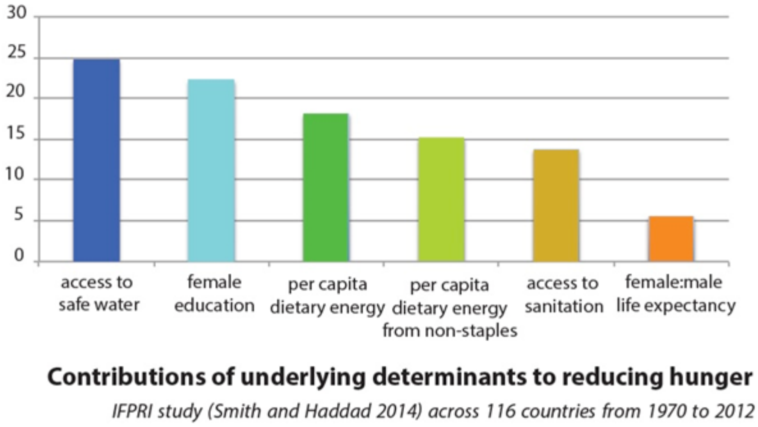
While these examples show that bridging between domains has been recognised as both useful and possible, it is also clear that these examples are relatively rare and much agroecology is often happens predominantly in terms of one cell only. Concerted efforts are needed to provide more examples and communicate what is achieved by them, which is likely be more effective than critiquing actors in one cell from the perspective of another.

3.2.4 How is agroecology valued?

Agroecosystems are valued in various ways such as through the lens of productivity alone versus multifunctional benefits including ecosystem services, community impacts, livelihoods, well-being.

Limitations of focusing on productivity: With the clear remit within the CFS to address FSN, especially of vulnerable communities including smallholder producers, those in protracted crises, women and children, a singular focus on productivity alone is not appropriate. The productionist argument, that the amount of food produced globally will need to either double (Tilman *et al,.* 2011), or increase by 60 per cent (Alexandratos and Bruinsma, 2012) have been tempered by the realization other conditions than simply production, contribute to alleviating hunger. A longitudinal study across 116 countries between 1970 and 2010 has shown that access to clean water and sanitation, and female education have been responsible for 68 per cent of the reduction in child malnutrition while increased food supply of staple foods accounted for only around 18 per cent (Smith and Haddad, 2015).

Figure 11 Determinants of hunger



Source: Smith and Haddad, 2014.

A recent parsing (Chappell, 2018) lays out the logic to suggest that the world currently produces almost enough food on a calorie basis for the estimated 9.14 billion people projected for 2050, even with no changes to diet or waste. Thus, meeting global needs in the future might best focus on changes in production systems that could conceivably slightly reduce yields in some regions to favour environmental benefits, but more generally address yield gaps through ecosystem services while focusing on diets and reducing food waste. Increasingly, the focus is on the nutritional quality of food produced, noting that the spectacular production increases of the last half-century have come from high-yielding and not nutrient-dense cereals, such that more food needs to be consumed to attain recommended dietary levels for many nutrients than in the past (DeFries *et al.* 2015).

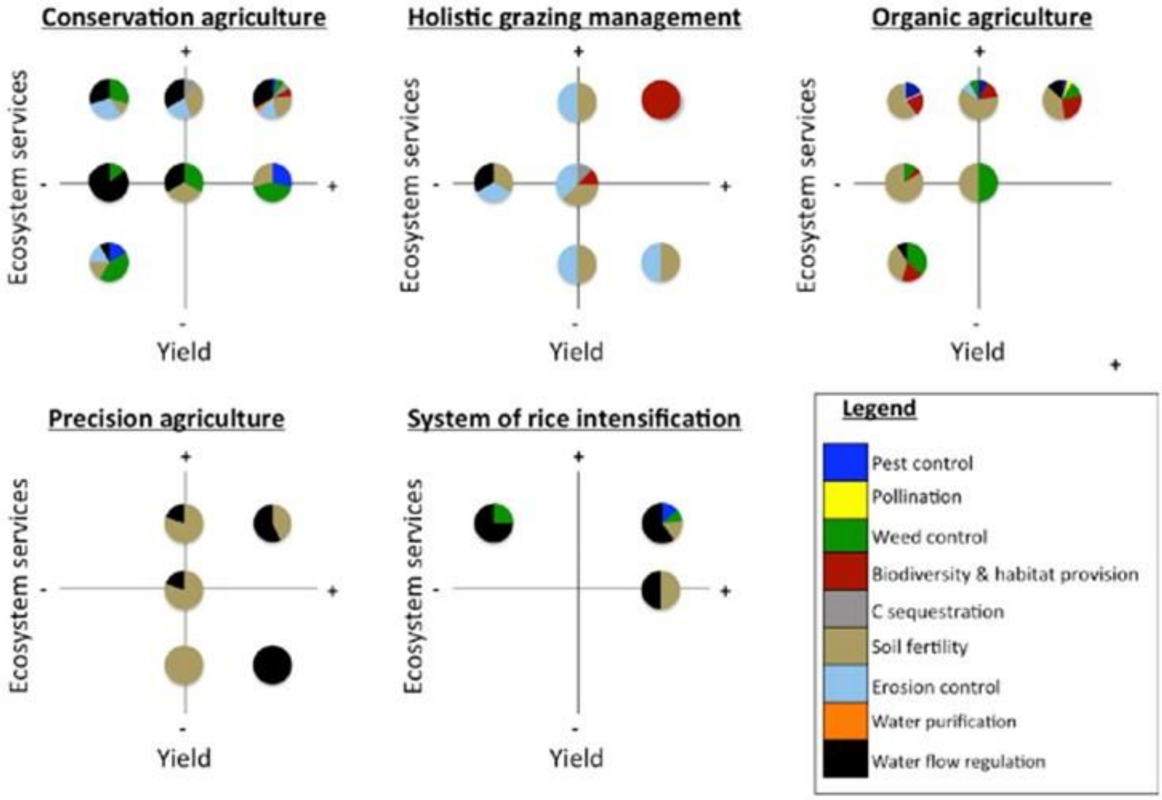
Valuation of multifunctionality: Multifunctionality, an often misunderstood term, points attention to the fact that agriculture and food systems serve many functions, in addition to food production. The term refers to the interconnectedness of agriculture with societies, economics, and the environment (IAASTD 2008, Royal Society 2009, Lovell *et al.* 2010). It does not imply that all farm operations must have multiple functions, but that farms and agricultural landscapes are and can be managed for multiple objectives. In the context of FSN, maximizing yields is often not the primary objective for many farmers; in the face of uncertainty around markets and climates, they may logically choose to manage their farm operations to reduce uncertainty and risk, increasing resilience by diversifying outputs.

Valuation of externalities: Over the last decade, there has been increasing attention given to the costs and risks of conventional agriculture, with its singular focus on maximizing productivity. These can generate extensive negative externalities from the degradation of water quality and quantity, greenhouse gas emissions, and disruptions of natural pest control, pollination, and nutrient cycling processes from agrochemical inputs (Diaz and Rosenberg 2008; Klein *et al.* 2007; Matson *et al.,* 1997; Campbell *et al.* 2017, Rasmussen *et al.,* 2018).

However, agroecosystems are capable of generating not just negative externalities, but many positive externalities. Agroecosystems can contribute substantially to building natural capital, creating the ecological infrastructure that facilitates natural pest control, nutrient recycling, and pollination, and of course produce food and forage. The agricultural production sector is a major employer of human resources, and has the ability to continuously build human capital, through training and knowledge exchange. The capacity of the agriculture sector to build social, financial and physical capital is also a significant input to local and national economies.

It has often been assumed that trade-offs are inevitable if agricultural policies support “alternative” systems that generate positive externalities, beyond production. But investigations are proving this not to be true. In a review evaluating evidence for yield and ecosystem service outcomes across five innovation approaches (conservation agriculture, holistic grazing management, organic agriculture, precision agriculture, and System of Rice Intensification), more than half of reviewed comparisons reported “win-win” outcomes, enhancement of both yield and ecosystem services, or “win-neutral” outcomes relative to conventional farming systems (Garbach *et al.* 2017) (see **Figure 12**).

Figure 12 Synergies and trade-offs between ecosystem services and yield in five "innovation systems"



Notes: Bubble location indicates a specific combination of outcomes for ecosystem services (y-axis: enhanced, upper quadrants; diminished, lower quadrants) and yield (x-axis: enhanced, right quadrants; diminished, left quadrants) relative to conventional farming systems. Bubbles located on the axis indicate no detectable difference from conventional farming systems. Coloured wedges within each bubble indicate the proportion of the comparisons reporting on each of the nine ecosystem services. A total of 181 comparisons were included, having data for both ecosystem services and yield.

Source: Garbach *et al.*, 2017

Valuation metrics: Considerable effort is going into developing new metrics in the valuation of agriculture and food systems to capture the complex realities and values in a more holistic, systems-based manner, avoiding the risks of simple metrics such as "per hectare productivity" (TEEB 2018). Increasingly, it is realized that it is important to look along the entire food value chain, from production to processing and distribution to consumption, to understand the impacts and dependencies throughout our food systems (e.g. Mannan *et al.*, 2018). In addition to biophysical flows along the food chain, there are critical aspects of how food systems impact human health, nutrition and social equity that have rarely been accounted for, yet have significant impacts on well-being. Finding new ways to measure these values can contribute to developing policies and decisions that address and respect the multiple values of food systems.

3.2.5 Access to technology and innovation: who benefits?

Some view innovation and technology as being synonymous with progress and growth. However, a critical assessment of a given technology has to be made in the light of who benefits, who bears the the costs and what are the trade-offs amongst these costs and benefits.

Technologies and innovation are vital to the achievement of the human desire to meet the needs for food, fibre and development. Important developments in humanity are associated with advances in science and technology (Sefer and Ercan, 2011) although other key developments have been due to social movements, and often a synergy of multiple factors. Some products of science tend to create a disruption in the existing balance of nature to produce the benefits attributable to the technologies (MaryAnne, 2015). Advances in technology will require input from various segments, and technology adoption can create multiple disruption with benefits as well as multiple trade-offs (Kremen and Miles, 2012). Some technologies benefit particular groups in society while being detrimental to others. For most technologies, the holistic assessment of the trade-offs on every other component of the systems are never truly carried out at the point of testing and release of the technologies (Altieri and Toledo, 2011). The concept of ”planetary boundaries” was developed by Rockström *et al.* (2009) to assess whether we are in a ”safe operating space” for humanity along nine key dimensions.

Box 14 Planetary Boundaries[18]

A group of 28 internationally renowned scientists identified nine processes that regulate the stability and resilience of the Earth system: climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biogeochemical flows (nitrogen and phosphorus), freshwater use, land-system change and biosphere integrity (Rockström *et al.* 2009). The scientists proposed quantitative planetary boundaries within which humanity can continue to develop and thrive for generations to come. Crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes. Researchers suggest that four of the nine boundaries have already been exceeded (Steffen *et al.*, 2015).

Global assessments of the current agriculture and food system suggest that it is a major driver of reaching planetary boundaries for climate change, biogeochemical flows and biodiversity loss (Campbell *et al.,* 2018; IPCC, 2014). Synthetic chemicals that are derived from petroleum and by-products and used in combination with other mined substances such as mineral fertilizers have dramatically increased biogeochemical flows of nitrogen (N) and phosphorus (P) and an overall release of greenhouse gases into the atmosphere, with definite effects (Campbell *et al.,* 2018). Although fertilizer use as a technology package has had tremendous effects on yield and productivity of many crops, primarily because of improved supply of nutrients to plants (Foley *et al.,* 2011), its misuse and overuse has had debilitating or disastrous effects on air pollution, biodiversity, coastal marine watersheds and greenhouse gas emissions (Campbell *et al.,* 2018; Steffen *et al.,* 2015). The same applies to other agrochemicals for pest control spanning through pathogens, diseases, insects and weeds, for example. The negative effects of agrochemical toxicities on non-target organisms are of huge concern for birds, insects and other biota, with dramatic biodiversity declines globally attributed in part to the rise in agrochemical usage (Goulson, 2014; Rasmussen *et al.,* 2018; Vanbergen and IPI, 2013). There are also human health concerns, particularly for those working directly in agriculture, including the children of farmworkers (Acury *et al.,* 2014; Marks *et al.,* 2010). Acute exposure of humans to pesticides can have toxicological symptoms, such as dizziness, muscle ache, nausea, and seizures, while repeated exposure has been associated with reduced cognitive, sensory and motor functions (De Silva *et al.,* 2006; Kamel *et al.,* 2003; Marks *et al.,* 2010).

There are increasing reports of accumulation of certain elements in poisonous proportion in plant and livestock tissues following long-term exposures (Christos and Eleftherohorinos, 2011), although in some cases there are claims of residue breakdown into non-toxic elements after some time. Multiple residues can be found today in food products, in particular in vegetables and fruits (Holme *et al.,* 2016; Hu *et al.,* 2016). The case of using herbicides to control weeds is also illustrative. Although not expected by experts from companies and universities, the broad and repeated application of glyphosate, a very effective herbicide, multiple resistance in weeds were detected within relative short time-span (Mortensen *et al.,* 2012; Shaner, 2014). One consequence is that farmers changed to even more toxic substances or applying a combination of different herbicides with tremendous effects on the environment. Weed resistance continues to be a major problem for farmers reliant on synthetic herbicides (Shaner, 2014).

Assessing technologies within the framework of sustainability is vital to effective agriculture and food systems. Promoting the use of specific technology should be built on numerous criteria, including economic feasibility, social equity, cultural acceptability, long-term resilience and environmental impacts. The end users of technologies may be quick to accept and use technologies once it offers economic returns without immediate and noticeable detrimental effects to that user, even if wider impacts are being experienced by others and by the environment (Seline *et al.,* 2015). The

[18] http://www.stockholmresilience.org/research/planetary-boundaries.html

assessment of the long-term, synergistic and broader effects of agriculture and food technologies needs to be carefully assessed and debated in public for building a deeper democratic food system that regulates the generation and release of technologies for use in agriculture with public goods in mind. This approach will take into account not only environmental impacts but also effects on vulnerable groups, including rural populations and the long-term resilience of the planet (Schipanski *et al.,* 2016).

It is essential to examine and ensure a balance between the costs and benefits that accrue to individuals and groups in society from specific technologies vis-à-vis the costs and benefits to the entire system and its various elements (Xin *et al.,* 2015). Using this kind of philosophy for assessment of technologies would provide a more sustainable appraisal method that would factor in the trade-off of technologies before they are released for use in agriculture. One example is about the potential use of GMOs for integrated pest management and biological control (Hokkanen and Menzler-Hokkanen, 2017). If carefully considered from the beginning, appropriately managed and not applied as a one-way, only technology, some people advocate that they could be considered under defined circumstances as an additional tool for biological pest control practices (see next Section for a fuller discussion on GMOs).

Agroecological approaches also require compatible technologies to ensure increased productivity and continuous outputs to meet the demands for food and balanced nutrients for healthy life. Taking agroecological principles into account will draw additional questions for the social, ecological impacts of a given technology in a particular agroecosystem. For example, there is a question about whether new digital technologies are suitable for agroecological production (Gkisakis *et al.,* 2017). These new digital technologies are often clearly market-oriented and might be costly tools for smallholder farmers, increasing inequality in the long-term. Further, while for example the decision support tools are simply based on models for optimizing conventional production, they often ignore ecological processes. New robots for mechanical weeding in vegetable production is another technology. There is a question as to if it can be used in agroecological production, given that weed management without herbicides is a crucial question, and where alternatives might be an increased number of mechanical passages with a tractor would increase soil compaction and fuel consumption. Robots in agriculture may reduce employment opportunities in the countryside, and further de-skilling of farmers, reducing the potential for more complex agroecological methods. Alternatively, there may be constraints to applying more hand-weeding, which is often constrained by labour costs and labour availability.

There are increasing discussions on the contribution of new technologies specific to agroecology, but only a limited number of studies have been done to date with different criteria, e.g. long-term planetary resilience, environmental impacts during development and production of tools and technologies, social impacts, and economic implications for different groups.

3.2.6 Can genetically modified organisms be part of SFS for FSN?

Genetic engineering or recombinant-DNA technology permits selective gene transfer from one organism to another and between species (Bawa and Anilakumar, 2013). Genetically modified organisms (GMOs) were discovered in 1946 (Clive, 2011) and first commercialized in 1993 in China followed by the United States in 1995 (Bawa and Anilakumar, 2013).There are considerable and often polarized scientific and public debates about the environmental, health, economic, social and political implications of GMOs (Kettenberg *et al.*, 2018). Some are concerned about the right of choice by consumers and the labelling of GMOs (Tsourgiannis, *et al.,* 2011). Other arguments against GMOs include the concern about cross-contamination and the inability to contain traits to the field or species. For example, concern of transfer of pollen grain from a GM to a non-GM plant and its effect on the local gene pool or the effects of residue from GM plants on the decomposer community (the macro and meso fauna that participate in the decomposition and nutrient release from plant residues), for which results have been variable (IRDC, 1998, Brake and Vlachos, 1998, Hammond *et al.,* 1996, Novak and Haslberger, 2000).

These objections to GM technology fall into three categories that are very different in nature and in prospects for reconciliation with proponents of the technology:

1. Moral stances or beliefs that it is wrong to directly manipulate the genetic make-up of organisms, often characterised by the notion of scientists ‘playing God’ or ‘interfering with nature’ and distrust by many people of the scientists and biotechnology companies involved (Flemming, 2004). Although initially these would appear irreconcilable with GMO technology,

debate persists about whether the reasoning underpinning some of these moral positions is consistent (Comstock, 2014).

2. Objections to GMO technology because it may disempower farmers and others by concentrating control of key agricultural resources (crop plants and animals) in the hands of corporations that can assert rights over them (World intellectual Property Organisation, 2018[19]). This could affect the progress of scientific research as well as affecting farmer practice if intellectual property rights imposed constraints, with the corollary argument that allowing ownership of GMOs is necessary to stimulate private sector investment. Although initially these objections would appear reconcilable with GMO technology if farmers and other people's rights could be appropriately protected, the slow progress in ensuring rights to food more generally and the trust issues referred to in 1) above mitigate against arriving at consensus.
3. Concerns that GMO technology many be dangerous and have unintended ecological consequences, including on human health. These risks are outlined above and below and would appear to be amenable to evidence-based debate, although people differ with respect to how stringently they judge a precautionary principle should be applied, which essentially represents judgement about the level of risk involved, which remains uncertain.

These types of objections to GM technology and their interactions with one another and arguments for the use of GM technology are outlined below.

Current use of GM technology: The most common GM crops in use are soybean, corn, cotton and canola bred for herbicide tolerance or insect resistance, or have stacked both of these traits (Bawa and Anilakumar, 2013). The most common type of insect resistant crop inserts a soil bacteria called *Bacillus thuringiensis* (Bt). In India, 10.8 million ha land, 93 percent of total cotton area is used for Bt cotton production (James, 2012), whereas 4 M ha in the United States of America and 3.5 M ha in China used for Bt cotton (Barrows *et al.,* 2014). In the United States of America, 28 M ha of land are used for genetically engineered maize, followed by 7.5 M ha in Brazil and 2.8 M ha in Argentina (Barrows *et al.,* 2014). There are also crops being bred for drought tolerance or increased nutritional value, but few are commercially available. In many countries, regulatory agencies use the "substantial equivalence" concept, which is "the idea that existing organisms used as food, or as a source of food, can be used as the 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), but "does not imply absolute safety of the new product; rather, it focuses on assessing the safety of any identified differences so that the safety of the new product can be considered relative to its conventional counterpart" (CAC, 2003, cited in NAS, 2016). In other countries, including the European Union, they place more emphasis on the precautionary principle, a deliberative principle that considers the health, safety and environmental aspects of a technology, and tries to minimize risks from that technology (NAS, 2016).

Addressing food FSN for vulnerable groups: One set of critiques of GM crops suggest that these crops are part of a technical, narrow and often industrial approach to agriculture and food, that assumes the problem of hunger is one of low productivity. This narrow, production-oriented approach assumes that a generalized solution for generic "poor people" in "developing countries" rather than underlying drivers of food insecurity and malnutrition such as inequality and poverty, which are context-specific (Moseley, 2017; Stone and Glover, 2017). The evidence for FSN impacts on vulnerable groups is limited and mixed. In the case of Bt cotton, which is the most studied GM crop in this regard, there are a range of results.

<u>Bt cotton</u>

- Pakistan: There is evidence of reduced pesticide use with Bt cotton in Pakistan (Qiao *et al.,* 2017) contributing to additional employment income for the poor and more equitable rural development (Kouser *et al.,* 2016)
- Studies may overstate impacts in Pakistan due to poor governance and labelling of Bt cotton (Cartel *et al.*, 2006).
- Many studies point to inconclusive results on yield and pesticide use, with enormous variability (Cartel *et al.*, 2006; Smale *et al.,* 2009). Some studies suggest that Bt cotton lowers pesticide use, thereby avoiding several million cases of pesticide poisoning in India and the accompanying saving in health costs (Kouser and Qiam, 2011). A more recent study found after

[19] See: http://www.wipo.int/reference/en/

an initial yield increase, yields have declined, with adoption of Bt cotton related to farmer bankruptcy and suicides in low-rainfall areas (Gutierrez *et al.* 2015).

- There are contrary examples in Burkina Faso and South Africa (see **Boxes 15** and **16**)

Box 15 Case of South Africa

Schnurr, 2012 evaluates the experiences of smallholder farmers in the Makhathini Flats, South Africa, who have been cultivating Bt cotton since 1998. There were high adoption rates achieved soon after its introduction that underpinned this initial period of success, and it served as an endorsement of GM technology. Makhathini's success was 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.

Source: Schnurr, 2012.

Box 16 Case of Burkina Faso

Four social and agro-ecological factors (credit, governance, seed price and pest dynamics) were assessed for Bt cotton outcomes for producers 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, demand greater attention since they are driving large numbers of producers to abandon all forms of cotton production. Bt cotton will control target pests, but secondary pests are likely to emerge shortening the benefits of the technology. These findings suggest that many issues with Bt cotton adoption in Burkina Faso lie in the social and agro-ecological context of adoption, which traditionally is not examined in farm-gate analyses of transgenic crop outcomes. An examination of relevant social and agro-ecological factors improves assessments of the likely outcomes of transgenic crops for producers, and allows for greater understanding of their differential impacts. (Bt cotton no longer grown in Burkina Faso).

Source: Dowd *et al.*, 2014.

GM maize

Proponents of GM crops argue that they may increase farmers' income and thus their economic access to food (Qaim and Kouser, 2013). In their review funded by Monsanto, Brookes and Barfoot (2017) showed that farmer incomes were increased with use of GM crops over a 20 year period (1996–2015). They found that these crops generated additional income of US$167.8 billion for farmers, with USD 81.7 billion generated in industrial countries and USD 86.1 billion in developing countries. In 2015 alone, net economic benefits at the farm level were estimated USD15.4 billion, with 49 percent to farmers in developed countries and 51 percent to farmers in developing countries. The net economic gains have been due to improved yield and production gains (72 percent) and cost savings (28 percent) (Brookes and Barfoot, 2017).

Box 17 GM maize

Meta-analysis (of peer-reviewed literature, 1996–2016) suggests yields were increased (5.6–24.5 percent) and GM maize had lower levels of toxins (Pellegrino *et al.,* 2018).

Mexico case study as the site of maize center of origin and diversity, as well as a place where maize has great food security, cultural significance and socio-economic impacts for smallholder farmers, has been a highly contested place in terms of the introduction of GM maize. The North American Free Trade Agreement allowed the importation of US grown maize, which had dramatic impacts on the economic viability of smallholder Mexican livelihoods, but also led to ongoing scientific, legal and political debates about the presence of transgene flow into Mexican landraces (Agapito-Tenfen and Wickkson 2018; Carro-Ripalda and Astier 2014; Mercer, Perales and Wainright 2012).

Golden Rice

At this stage there is no documented evidence of improved nutrition from GM crops, although there is a hope that through this technology nutritional deficiencies may be reduced (De Steur *et al.,* 2012). In May 2018, the US FDA provided a positive food safety and nutritional evaluation of Golden rice, although they noted that it did not have high levels of Vitamin A. An economic analysis of costs and benefits suggested that the delay in the approval for use of GM Vitamin enriched rice (Golden rice) resulted in ~1.4 million life years lost in India over a decade (Wesseler and Zilberman, 2014). Critics of Golden rice note that this technical approach to addressing nutrition fails to address the socio-economic, political and ecological factors which cause micronutrient deficiencies, which vary by place but include reduction in diverse farming systems (and thus vitamin A rich foods) and social inequalities such that people cannot purchase vitamin A rich foods (Stone and Glover 2011; Nestle 2001).

GM bananas

Addison and Schnurr (2016) examined the introduction of a GM crop resistant to banana bacterial (BBW) and found that it might potentially impact labour dynamics in Uganda. Although there might be increased yields for small-scale farmers with the introduction of GM technology, this is expected to intensify agricultural labour burdens of women.

Environmental, social and political impacts: Proponents of GMO crops suggest that they provide novel pest and disease management approaches and reduce pesticide use. In Hawaii, papaya production is based for 80 percent on genetically engineered varieties resistant to papaya ring spot virus (Bawa and Anilakumar, 2013). A meta-analysis of the agronomic and economic impacts of GM crops showed that adoption of GM technology reduced use of chemical pesticides by 37 percent, increased the yields of crops by 22 percent and increased the profits of farmers by 68 percent (Klümper and Qaim, 2014). However these authors indicated that a limitation of the meta-analysis was that earlier studies included in the analysis did not report sample size and variance measures. Advocates of GM technology argue that use of GM increased agricultural production by over USD 98 billion, and reduced use of pesticides by 473 million kg.

Insect pest resistance to GM crops has occurred in other crops, however, and critics argue that reliance on a few GM crops may reduce smallholder farmer resilience and adaptability under changing agroecosystem conditions. Critics of GM crops argue that these technologies can have significant detrimental environmental impacts, such as rising insect and herbicide resistance (Shaner, 2014; Tabashnik *et al.,* 2013). Agrobiodiversity may decline over time with increased prevalence of monocropping and reliance on purchased inputs, as does farmer knowledge of breeding, cross-pollination and more complex agroecological management of ecosystems (Johns and Ezyaguirre, 2007; Stone, 2007).

The crops, which must be purchased each year, and often require the application of fertilizers and/or herbicides for effective yields, increase corporate control over the input side of agricultural production (Howard, 2015). Relatedly, given the dominance of a few corporate players in the scientific research in this arena, there is a concern that industry, promoting these crops for profit-based motives, influence what kind of research gets done on these products, with scientists that question genetically modified crops often facing intense public scrutiny that may jeopardize or limit democratic, open and transparent public dialogue (IARC, 2018; Scoones, 2002).

Health impact: There are ongoing scientific debates about the health impacts from GM crops, with some studies providing evidence of the potential long term effects on human health (Séralini *et al.,* 2011). Studies of GM show that the GM biomass *"can be safely used in animal feed and rDNA fragments have never been detected in products (eg milk, meat and eggs) derived from animals that consumed genetically engineered feed"* (van Eenennaam, 2013).

In February 2018, approval was granted by Food Standards Australia New Zealand (FSANZ) for high DHA (docosahexaenoic acid) canola oil from GM canola to be used as human food. Proponents argue that the availability of a land-based source of a long chain omega-3 oil (DHA canola) will contribute to sustainability of fish populations by providing an alternative to fish and algal oils. These claims are yet to be tested, since people who consume this GM canola oil may not reduce their fish consumption. Reliance on GM crops can further the homogenization of diets associated with problems of over nutrition.

Relationship to agroecology: The environmental, social and economic impacts of GM technology are being questioned by critics (Gilbert, 2013). Despite the uptake of GM technology, and the many reports in the scientific literature on the risks and benefits of GM, there is public mistrust in GM technology (Andreasen, 2014). The GM debate continues to be very polarizing 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).

3.3 Roles of agroecology and other innovations for enhancing FSN

There is unequivocal evidence that supports the important role of agroecology for enhancing FSN, with benefit demonstrated at a social, environmental and economic level. However, there are strength(s) and constraints of agroecology and other innovations, which may differ depending on the relative importance of the various factors influencing FSN in different regions and communities. The "appropriateness" of an innovative practice or technology should be assessed in the light of its purpose, results, and impacts in a specific context. One approach may be suitable for a region or community may not be suitable for another as the dynamics of the whole ecosystem has to be considered.

From the elaboration of the divergent narratives, the following conclusions are drawn:

Can innovation approaches embrace both small- and large-scale operations? The innovation approaches should accept that both small and large farms contribute to FSN provided the farms produce a range of agricultural products. This is because farms of any size with higher agricultural diversity produce more nutrients that are needed for FSN. However at present, small and medium-sized farms produce more food and nutrients in the most populated regions of the world than large farms in modern food systems.

Can agroecology feed the world? There appears to be considerable potential for agroecology to contribute substantially to feeding the word, not only through specific practices at farm level but also from taking a more holistic and transdisciplinary approach to whole food systems. Positive impacts of adopting agroecology on yields and profits have been documented but their global relevance has not yet been fully assessed. Further clarity of what defines the boundaries for classification of agroecological practices and agroecological farming systems are required for a clear case to be made, based on what is considered "in" and what is considered "out" as agroecological principles are variably applied by different practitioners. There are many examples from tropical and subtropical countries where significant yield increases, increased farm profitability and more equitable outcomes have been associated with application of agroecological principles, which suggest that it can continue to play a prominent role in achieving FSN and deserves greater investment in research to understand and quantify the benefits it can bring across a range of contexts.

Are global science and local knowledge opposed in agroecological thinking and practice? The value of agroecology may be seen at various levels in farm and regional communities and within specific domains in the food ecosystem. A greater appreciation of agroeocology would benefit from more boundary-spanning work between local communities and the wider science community who may hold different views about what is considered useful knowledge. The bridging of the knowledge gap between informal indigenous knowledge and practices and the more formal science that underpins industrial agriculture will be required, as these facilitate greater connections between domains. The reciprocal learnings from each, if combined, are more likely to result in SFSs than either alone.

Access to technology and innovation: who benefits? There needs to be a critical assessment of a given technology - who benefits, who bears costs and what are the trade-offs from the innovation. Some technologies may be disruptive and inputs from various stakeholders for a holistic assessment of the trade-offs on all components of the food ecosystem are required. Technologies should be assessed within the framework of sustainability and based on various criteria, including economic feasibility, social equity, cultural acceptability, long-term resilience and environmental impacts, also with particular considerations about the impact on vulnerable communities.

How is agroecology valued? There are various ways in which the value and impact of agroecology towards SFS can be measured. Depending on the metrics used (e.g. productivity alone versus multifunctional benefits including ecosystem services, community impacts, livelihoods, well-being) and assumptions made, there might be differences in how agroecology is valued. There is a need for new metrics for evaluation of agriculture and food systems to capture the complex realities and values in a more holistic and systems-based manner which recognises value capture along the whole food supply chain and the food system.

Should genetically modified organisms be used for improving FSN? There is no consensus on this. Proponents of GM technology assert that there is a place for GM technology in SFS for FSN and that it can contribute to the realisation of some agroecological principles provided that the social, economic, safety and health aspects of GM technology are appropriately regulated and that there is sufficient evidence to ensure that vulnerable groups are not disadvantaged when the technology is introduced. They indicate that education about the effects of GM and transparency in labelling will need to accompany introduction to allow consumers to make their own decisions about purchases. Others, and many proponents of agroecology consider that GM technology is either in principle, or in practice incompatible with SFS for FSN on the basis of objections that are moral, relate to property rights or to the unpredictable ecological consequences, including possible human health impacts.

A systems-based approach which links the provision of safe and nutritious food from productive agriculture systems through sustainable supply chains to all people is required. However, although there is sufficient food produced, there are inequities in food distribution, access and food utilisation. There is a need to address underlying factors, apart from food production, such as income, conflict, inequality at multiple scales, environmental conditions, health care, consumption and childcare practices before FSN can be achieved.

4 ENABLING CONDITIONS FOR INNOVATION IN SFS FOR FSN

Building on the analysis presented in previous chapters, this chapter suggests priorities for action, enabling policies, interventions, institutional arrangements and organizational changes necessary to support innovations and enable positive changes for sustainable agriculture and food systems that enhance FSN. This embraces a solution-oriented framework, illustrated by a regionally balanced set of case studies, that paves the way towards concrete policy recommendations. The recommendations are based on careful exploration of the different enabling conditions for innovation necessary to achieve FSN reported in Chapter 2, as informed by related controversies and challenges that are discussed in Chapter 3.

4.1 Key elements of polices for SFSs for FSN

The different approaches profiled in this report (Agroecology, Sustainable Intensification, Organic Agriculture, Agroforestry, Climate Smart Agriculture, Permaculture, Nutrition sensitive agriculture, Sustainable food value chains, and Rights based approaches) have different implications for sustainable food systems aiming to achieve food security and nutrition although none of them alone address all of the aspects required for its delivery. Some approaches converge and overlap in aspiring to make a fundamental transformation of whole food systems to achieve SFS for FSN (e.g. agroecology, rights-based approaches and permaculture). Other approaches have shown sustainability outcomes focused on parts of food systems (e.g. agroforestry), or have more focused aims, so that their outcome for SFSs and FSN overall are unclear (e.g. climate smart agriculture, and sustainable intensification). Progress towards FSN requires drawing from experience and best practice across these approaches, particularly the integration of rights based approaches in conjunction with efforts to develop and promote more sustainable farming and extending the scope of actions to encompass entire food systems from production through to consumption. Without explicit attention to social equity, agency, utilization and environmental impacts, some approaches may not foster a SFS that can explicitly address FSN (Pimbert and Lemke 2018 and see **Table 3**). Key changes in the emphasis of policies pertaining to agriculture and food that could contribute to innovation in SFSs for FSN evident from analysis of innovation approaches in this report are briefly outlined below.

- Putting greater emphasis on health and nutritional benefits, as have been pursued within nutrition-sensitive agriculture and organic agriculture, into food and agriculture policies. Bringing in an awareness of nutrition and health has expanded the understanding of how policies can be oriented 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 below). Too often agricultural development policies have overlooked how critical this is, and what the impacts may be of not taking gender and other social inequities fully into account, often worsening FSN outcomes.
- Focusing effort on areas where evidence suggests fastest progress can be made in achieving FSN outcomes. There is evidence that novel pathways toward SFSs for FSN that are quite different from a focus on increasing production that has characterised the past can be efficient and effective in delivering FSN outcomes. For example, the role and contribution of education, particularly girl's education, has been demonstrated to be the second most significant driver of child nutritional status, after safe water (Smith and Haddad, 2015; Semba *et al.,* 2008; Ruel *et al.,* 2013). Other routes that are less explored in agricultural and food policy include facilitating womens' empowerment and rights based approaches more generally.
- Putting greater emphasis on processing, distribution, market and consumption aspects of food systems. While food and agriculture policies have often concentrated on improving conditions in the production end of food value chains, the approaches of nutrition sensitive agriculture, sustainable food value chains and reducing food loss and waste bring attention to key levers along other parts of the food chain. The improvement of sustainability in agriculture will not occur on the production side alone, but will depend on connections within the chain, forging multi-stakeholder collaborations, for collective achievement of better environmental, business and societal outcomes. For example, the process of creating participatory guarantee schemes involves building stronger socio-economic relationships between producers and consumers (**Bo19**). Equally, for reducing food waste and thus increasing the supply of food, greater

consumer awareness with involvement of all stakeholders along the supply chain and standards-setting organizations is an important step towards reducing food loss and waste.

Box 18 Green and organic participatory guarantee schemes in India

To be further elaborated

http://www.pgsindia-ncof.gov.in/

- Broadening the frame of agricultural incentives to include multifunctional sustainability indicators covering all ecosystem services (ES) and implementing policy at appropriate scales to manage ES provision (see Section 4.2.1). Often agricultural incentives focus on achieving single outcomes such as fertiliser or pesticide subsidies increasing yield or agrienvironmental schemes conserving habitats, and they may conflict, so that managing trade-offs amongst impacts of land use on ES becomes critical (Jackson *et al.*, 2013). There is a need to measure agricultural performance as the sum of its impact on all the provisioning, regulating and cultural ES and their societal weighting and evaluate trade-offs and synergies amongst them (van Noordwijk *et al.*, 2018). This requires development of social capital and policy processes implemented at the local landscape scales at which key ES manifest (Pagella and Sinclair, 2014; Crossland *et al.*, 2018).
- Reconfiguring knowledge generation and sharing for innovation in agricultural and food systems. 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 knowledge 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 FSN. In large part, the role of co-creating knowledge between farmer organizations and researchers has been promoted amongst small-scale farmers and community-based organizations, as a distinct pathway towards innovation instead of technology transfer. Examples of these approaches are found in the Malawi case study (**Box 6**), Prolinnova, the McKnight Foundation's Collaborative Crop Research Programme, and the Food Security and Sovereignty in the Segovias project in Nicaragua (FAO, in preparation).

4.2 Enabling conditions for appropriate institutional arrangements for SFSs for FSN

From the approaches and narratives explored in this document (Chapters one to three), it is possible to identify key aspects of the enabling conditions for institutional arrangements and organizational change necessary to support SFS for FSN, these are set out below grouped under six categories of action.

4.2.1 Support for diversified farming systems

Significant scientific literature and policy reports have outlined the environmental, social, health and political impacts of the currently predominant industrial agricultural and food system, as well as reasons for its intransigence (Campbell *et al.,* 2017; IPES-Food 2016; HLPE 2017; Vanloequeren and Baret 2009). Designing enabling conditions and policies in part require **shifting public support** towards more diversified farming. The previous chapters outline how small and medium sized farms make important contributions not only in terms of food supply and diverse crops, but also have high potential for applying agroecological approaches, with enough support. 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 and 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 chemical inputs while giving incentives for sustainable food production methods, or managing multi-functional landscapes including wild species (Loconto *et al.* 2018; IPES-Food 2016). It should be noted that a substantial barrier to securing such premiums is market failures to not cost 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**).

Box 19 Agroecological movement in Cuba

To be further elaborated

Sources: from Mier y Terán Giménez Cacho *et al.* 2018 and other sources).

4.2.2 Recognising the role of policy over access to natural resources

The tenure of farmers over resources often claimed by the state such as trees (**Box 21**), or land (**Box 20**) may be the pivot ensuring farmer investment in more sustainable forms of production. Barriers to diversification of food systems, a key aspect of a SFS, 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 heterogenous varieties, including traditional crops, is an important component of this. Large-scale land acquisitions that result in loss of access to natural 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, 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. Rights-based approaches articulate the importance of enabling environments that advance equitable trade relationships, land reform, protection of intellectual and indigenous land rights, and gender equity, and call for trade and market arrangements to be transparent, democratic and equitable.

Box 20 Land rights and public procurement policy as a key dimension of SFSs for FSN. Food Sovereignty and Fome Zero: Connecting Public Food Procurement Programmes to Sustainable Rural Development in Brazil

To be further elaborated

Source: Wittman and Blesh 2017.

Box 21 Decentralisation of forest authority in Kenya, issues of agency in community control of forest resources

To be further elaborated

Source: Chomba *et al.*, 2015.

4.2.3 Leveraging purchasing powers

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 sustainable food systems. 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 (**Box 22**) is instructive here, as an example 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 in 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 very effective at addressing FSN while supporting SFSs (**Box 22**).

> **Box 22 Case of Belo Horizonte, Brazil – city invests to address food security and nutrition**
>
> To be further elaborated
>
> Source:

4.2.4 Supporting equitable and sustainable food value chains

Supporting equitable and sustainable food value chains (Loconto *et al.,* 2018) is a key enabling condition for development of SFS for FSN. Quality control systems must be adapted to local needs and conditions, and partnerships between public, private and civil society actors can foster livelihood improvements for producers. Farmers who use sustainable approaches such as agroecology need markets, and consumers need better access to such markets. Supporting short supply chains and alternative retail infrastructures, such as farmers markets, fairs, food policy councils, local exchange and trading systems, will help enhance farmers' livelihoods and increase access to local, sustainably produced and diverse food (Loconto *et al.* 2018; Van der Ploeg *et al.,* 2014). 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 agrocological 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;
- support the creation of viable farmer associations, that share knowledge and create strong networks to leverage the inputs (including alternative inputs, such as cover crop seed) needed;
- 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 (See **Box 18** in Section 4.1)
- Development 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 multistakeholder platforms focused on local and regional markets.

> **Box 23 Kom Kelluhayin Corporation, Chile**
>
> (Example of a partnership between indigenous groups, restaurants, university, Ministry of Agriculture and consumers.)
>
> To be further elaborated
>
> Source: Loconto *et al.* 2018

4.2.5 Public education and awareness raising

The need for public education and awareness raising about SFSs for FSN, that uses democratic, grassroots approaches is a key enabling condition for transforming food systems. Examples of successful 'scaling out' of SFSs, including agroecology, have often involved public awareness campaigns that worked to change dominant narratives about the food system (Loconto *et al.* 2018;

Chappell 2018), and the actions of communities. Public awareness to enable and foster innovations in SFSs should go beyond simple awareness campaigns, to engage citizens in ”democratising innovation”- sharing information and knowledge across networks, addressing social problems, and co-producing solutions amongst communities and researchers Schot & 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).

4.2.6 Supporting the involvement of civil society groups in governance forums

A final enabling condition that builds on raising public awareness is to actively support the involvement of diverse civil society groups in governance forums at different scales. Global institutions which 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. The CFS, can serve as a model of inclusive civil society involvement and a starting point for shifting the power dynamics within global governance systems. Food planning processes at multiple levels can help to make this fundamental shift in the food system, through processes such as:

- territorial management planning to identify relevant ecological practices, protection of common areas for water, forest and other resources can be encouraged at a regional level (Caron *et al.*, 2018; **Box 24**);
- Inter-ministerial mechanisms should be used at the national level to bring together ministries of agriculture, health, gender, environment and education, with mechanisms to include diverse stakeholders, including the rural poor, women, youth and other relevant stakeholders in planning and implementing measures to build sustainable food systems for food security and nutrition;
- Development of National Food Policies to set long term goals at a national and regional level. Democratic, grass-roots consultative processes including involvement of scientists, indigenous groups, farmer cooperatives, and other stakeholders.

Box 24 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’ who presented an alternative program to the President of Brazil and the provincial governments. They developed a notion of ‘*co-existence with semi-aridity*’ which emphasized 1) conservation and sustainable use of natural and water resources and 2) 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 labor, cooperatives, rotating solidarity funds, participation in public programs such as the National School Food Program, Program for Family Farms and farmers markets. These innovations were grouped under the category of “partnerships, organization and synergistic relationshiops between diverse actors” (Pérez-Marin *et al.* 2017).

Source: Pérez-Marin *et al.* 2017.

4.3 Reconfiguring knowledge generation and sharing and strengthening investment in research and development.

A recurring theme throughout this report, has been the need to change the relationship between formal 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. 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 to address knowledge gaps and span boundaries between social movements operating with strongly held convictions that motivate action towards more sustainable agricultural and food systems at grassroots level, and formal research systems that are often antagonistic rather than supportive of the knowledge base on which social movements base their action.

4.3.1 Public and private investment in research

Strengthened *investments* are needed in agricultural and food systems research and development (R&D) (FAO, COAG/2016/6). Between 2000 and 2009, global expenditure on agricultural R&D increased by 3.1 percent a year in average (only 2.3 percent a year in low-income countries), from USD 25 to USD 33.6 billion, almost half of this increase being spent in China and India (FAO, 2017). FAO estimates that three quarters of investments in agricultural research and extension are realized in G20 nations (FAO, COAG/2016/6) . Global R&D investments are focused mainly on major staple crops and other, more nutritious crops (such as pulses, fruits, vegetables, as well as the so-called orphan crops) are often neglected (GloPan, 2016; HLPE, 2017b).

Box 25 The African Orphan Crops Consortium and African Plant Breeding Academy

To be further elaborated

Source: http://africanorphancrops.org/

FAO (2014) 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 USD 12.9 to USD 18.2 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 USD 40 billion (in PPP) 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 like China and India (Beintema *et al.,* 2012; Pardey and Beddow, 2013).

Recent evaluations suggest that public funding of international agricultural research generate very high returns on investment. With the economic return from control of cassava mealybug in Africa through release of biological control agents alone sufficient to justify global investment in agricultural research (Nweke, 2009). Analysis of the impacts of its control in Asia illustrate how a good systems understanding 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 the innovation process, from invention to commercialization,[20] and that appropriate public-private partnerships can be helpful in intermediary stages of this process. FAO (2014) 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 to countries with more limited research and development capacities (FAO, 2014).

Action is required in three key areas:

- Rebalancing the relative contribution of public and private funding of research and development in agriculture and food systems and clarifying the respective roles and responsibilities of public and private actors in the innovation system.
- Supporting new ways forward for R&D institutions so that they are better fit to address whole food systems and transdisciplinary research along food value chains. Beyond their traditional focus on agricultural production and productivity, R&D institutions should adopt a food system

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

perspective, cover all the dimensions of sustainability and find ways to reconcile multiple objectives and to improve FSN while preserving the ecological basis of food production in the future.

- Reconfiguring the relationship between formal scientific research and local *knowledge systems* can help design innovative pathways to sustainable productivity growth and agricultural development. *Participatory R&D* methods, involving small food producers, as well as their local communities and organizations, can help ensure that the results meet their needs and expectations and consider their experience (FAO, 2014; . FAO and INRA, 2016; HLPE, 2016, 2017b). See also Section 4.3.2 below.

4.3.2 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, 2014). Improving *access of small food producers* (including small farmers, pastoralists, fisher-folks, and forest-dependent people), in particular women, to extension services will be critical to fill the gaps in yield, information, knowledge and technology and contribute to a wider adoption of sustainable agricultural practices: producers organizations and communities are expected to play a central role in that perspective (FAO, 2014).

Continuous learning throughout the life time 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 and strong emphasis on rote learning"* (World Bank, 2010). Community-based learning systems, such as Farmer Field Schools[21] 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, 2014) . Information and communication technologies (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, 2014; FAO, COAG/2016/6; FAO, 2017).

Diverse farmer and consumer-led initiatives around the world have led to positive changes for sustainable food systems that enhance FSN. One key area of public investment in programmes and interventions that foster innovations are 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 approaches and other sustainable food system 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 know-how and knowledge in the introduction of new practices and collective decision making. Such training and capacity building will help address the knowledge-intensive nature of agroecology, organic farming and permaculture through providing greater education and information.

- Creation of "lighthouses" – societies or training centers 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);
- Support alliances between small-scale producers and civil society groups in urban areas focused on food justice and sustainable food systems;
- In response to community-defined needs, investment in key aspects of the food value chain- for example small scale processing plants or storage facilities- can be catalytic toward changing food systems and enlarging their scope to address food nutrition and security.

[21] https://en.wikipedia.org/wiki/Farmer_Field_School

4.4 Acknowledge and enhance the specific role of women and youth for innovation

There is need for greater focus on gender and other social inequalities, including the position and opportunities for young people in agriculture and in achieving FSN. These have been highlighted throughout Sections 4.1 through 4.3 because they are important in addressing all aspects of agricultural and food systems rather than representing niche concerns. Six key dimensions in addressing issues involving gender and young people are set out here.

- Recognising women's central roles in agricultural and food systems, to help build the next generation agriculture and food systems on the firm foundation of their knowledge of their crop production, food processing and food provision practices.
- Recognising the often higher labour demands in holistic agricultural management systems and seeking greater income equity for those providing labour.
- Developing interventions that provide strategies and tools to deliver nutrition sensitive agriculture, including homestead food production systems, aquaculture, dairy, small livestock rearing, crop diversity and value chains for nutritious foods
- Support for Farmer-led food sovereignty and agroecology initiatives that advocate for women's formal rights to land access, and more equitable family and community relationships
- Reorienting institutions and organizations to explicitly address gender inequalities, including girls' access to education
- Recognizing the particular constraints and challenges that young peole face in trying to establish diversified farming systems and agribusinesses (**Box 26**), including access to land.

Box 26 The blueMoon agribusiness incubator in Ethiopia

blueMoon is an agribusiness, agri-tech incubator and seed investor who aim to match exceptional startup ideas from young entreprenuers with founder teams and the support and seed funding needed to bring them to fruition.

To be further elaborated

Source: http://www.bluemoonethiopia.com/

CONCLUSION

To be developed

ACKNOWLEDGEMENTS

To be developed

APPENDIX

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.[22]

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 13**) 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.

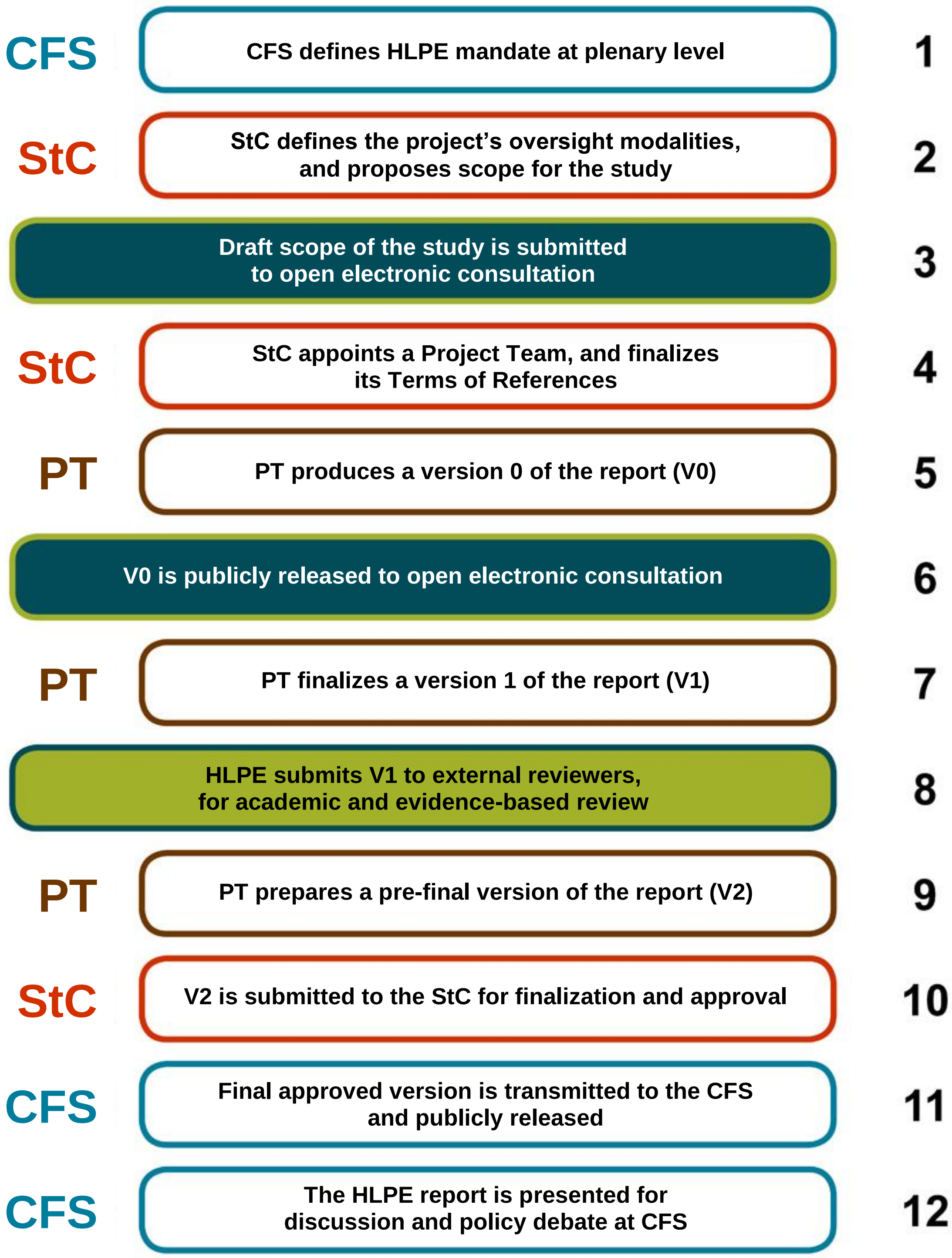
It includes an external scientific peer-review on a pre-final draft. The report is finalized and approved by the Steering Committee during a face-to-face meeting.

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

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

Figure 13 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

REFERENCES

To be finalized

Acury *et al.,* 2014

Agapito-Tenfen, S. Z., & Wickson, F. (2018). Challenges for transgene detection in landraces and wild relatives: learning from 15 years of debate over GM maize in Mexico. *Biodiversity and Conservation*, *27*(3), 539–566. https://doi.org/10.1007/s10531-017-1471-0

Agroecology Europe 2017

Agropolis. 2013. DMC—an ecological intensification engineering tool. www.agropolis.org/agronomy/research.php?id=10.

Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G. & Vaz, A. 2013. The women's empowerment in agriculture index. World Dev., 52: 71–91. http://dx.doi.org/10.1016/j.worlddev.2013.06.007.

Alkon, A.H. 2014. Food justice and the challenge to neoliberalism. Gastronomica, 14 (2): 47–70.

Altieri and Toledo, 2011

Altieri, M.A. & Nicolls, C. 2005. *Agroecology and the search for a truly sustainable agriculture.* United Nations Environment Programme, Mexico. www.agroeco.org/doc/agroecology-engl-PNUMA.pdf.

Altieri, M.A., Funes-Monzote, F.R. & Petersen, P. 2012. Agroecologically efficient agricultural systems for smallholder farmers: contributions to food sovereignty. *Agronomy for Sustainable Development,* 32(1): 1–13. https://link.springer.com/content/pdf/10.1007%2Fs13593-011-0065-6.pdf

Altieri, M.A., Nicholls, C.I., 2003. Soil fertility management and insect pests: harmonizing soil and plant health in agroecosystems. Soil Tillage Res. 72, 203–211.

American Academy of Pediatrics (2012)

Anderson & Sinclair. 1993. Ecological Interactions in Agroforestry Systems. Agroforestry Abstracts 6(2): 57-91 and Forestry Abstracts 54(6): 489-523

Anderson, K., Pimbert, M. & Kiss, C. 2015. *Building, defining and strengthening agroecology.* ILEIA and Centre for Agroecology, Water and Resilience, Coventry University, UK. http://www.agroecologynow.com/wp-content/uploads/2015/05/Farming-Matters-Agroecology-EN.pdf

Arimond, M., Hawkes, C., Ruel, M.T., *et al.* 2011. Agricultural interventions and nutrition outcomes: lessons from the past and new evidence. In: B. Thompson, & L. Amoroso eds. Combating micronutrient deficiencies: food-based approaches. Rome: CAB International, Food and Agriculture Organization, p. 41–75.

Arimond, M., Wiesmann, D., Becquey, E., Carriquiry, A., Daniels, M. C., Deitchler, M., *et al.* 2010. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. *Journal of Nutrition,* 140(11): 2059S–2069S.

Astier, M., Argueta, J.Q., Orozco-Ramírez, Q., González, M. V., Morales, J., Gerritsen, P.R.W., Escalona, M.A., Rosado-May, F.J., Sánchez-Escudero, J., Martínez Saldaña, T., Sánchez-Sánchez, C., Arzuffi Barrera, R., Castrejón, F., Morales, H., Soto, L., Mariaca, R., Ferguson, B., Rosset, P., Ramírez, H., Jarquin, R., García-Moya, F., Ambrosion, M. & González-Esquivel, C. 2017. Back to the roots: understanding current agroecological movement, science, and practice in Mexico. *Agroecology and Sustainable Food Systems*, 41(3–4): 329–348. https://doi.org/10.1080/21683565.2017.1287809

Augustin, M.A., Riley, M., Stockmann, R., Bennet, L., Kahl, A., Lockett, T., Osmond, M., Sanguansria, P., Stonehouse, W., Zajac, I., Cobiac, L. 2016. Role of food processing in food and nutrition security. Trends in Food Science & Technology 56:115-125. https://www.sciencedirect.com/science/article/abs/pii/S0924224415301886

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Jahi Chappell, M., Avilés-Vázquez, K,. Samulon, A. & Perfecto, I. 2007. Organic Agriculture and the Global Food Supply. Renewable Agriculture and Food Systems, 22(2): 86–108. https://doi.org/10.1017/S1742170507001640.

Badgley, C.; Moghtader, J.; Quintero, E.; Zakem, E.; Chappell, M.J.; Aviles-Vazquez, K.; Samulon, A.;Perfecto, I. Organic agriculture and the global food supply. Renew. Agric. Food Syst. 2007, 22, 86–108.

Bailey, 2018

Baldwin, G. 2005. Permaculture Definitions. Permaculture Activist.

Bàrberi, P., Burgio, G., Dinelli, G., Moonen, A.C., Otto, S., Vazzana, C., Zanin, G., 2010. Functional biodiversity in the agricultural landscape: relationships between weeds and arthropod fauna: Weed-arthropod interactions in the landscape. Weed Res. 50, 388–401.

Barrett, C. B. Bellemare, M. F., Hou, J. Y. 2010. Reconsidering Conventional Explanations of the Inverse Productivity-Size Relationship. *World Development*, 38(1): 88–97. SSRN: https://ssrn.com/abstract=1275353.

Barrios, E., Coutinho, H.L.C. & Medeiros, C. a B. 2012. *InPaC-S : Participatory Knowledge Integration on Indicators of Soil Quality Methodological Guide*. Nairobi, World Agroforestry Centre, Emprapa, CIAT. 180 pp.

Barthel, S., Crumley, C. & Svedin, U. 2013. Bio-cultural refugia - Safeguarding diversity of practices for food security and biodiversity. *Global Environmental Change,* 23: 1142-1152. doi:10.1016/j.gloenvcha.2013.05.001

Bawa, A.S. & Anilakumar, K.R. 2013. Genetically modified foods: safety, risks and public concerns—a review, *J Food Sci Technol.,* 50(6): 1035–1046.

Beintema, N., Stads, G., Fuglie, K. & Heisey, P. 2012. *ASTI global assessment of agricultural R&D spending. Developing countries accelerate investment*. Washington, DC and Rome, IFPRI (International Food Policy Research Institute), ASTI (Agricultural Science and Technology Indicators initiative) and GFAR (Global Forum on Agricultural Research). http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/127224/filename/127435.pdf

Bennett, A.B., Chi-Ham, C., Barrows, G., Sexton, S. & Zilberman, D. 2013. Agricultural Biotechnology: Economics, Environment, Ethics, and the Future. *Annual Review of Environment and Resources*, 38: 249–279.

Berkes F. and C. Folke, eds. 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge, UK: Cambridge Univ. Press.

Berners-Lee, M., Kennelly, C., Watson, R. & Hewitt, C.N. 2018. Current global food production is sufficient to meet human nutritional needs in 2050 provided there is radical societal adaptation.Elem Sci Anth, 6: 52. DOI: https://doi.org/10.1525/elementa.310

Bezner Kerr, R. 2012. Lessons from the old Green Revolution for the new: Social, environmental and nutritional issues for agricultural change in Africa. *Progress in Development Studies*, 12: 213-229.

Bezner Kerr, R. and M. Chirwa. 2004. Soils, Food and Healthy Communities: Participatory Research Approaches in Northern Malawi. *Ecohealth* 1 (Supplement 2): 109-119.

Bezner Kerr, R. E. Lupafya, L. Shumba, L. Dakishoni, R. Msachi, A. Chitaya, P. Nkhonjera, M. Mkandawire, T. Gondwe and E. Maona. 2016. “Doing Jenda Deliberately” in a Participatory Agriculture and Nutrition project in Malawi. J. Njuku, A. Kaler, J. Parkins (eds). 2016. In: *Transforming Gender and Food Security in the Global South*. London: Routledge, p. 241-259.

Bezner Kerr, R., C. Hickey, E. Lupafya and L. Dakishoni. 2018. Repairing Rifts or Reproducing Inequalities? Agroecology, Food Sovereignty, and Gender Justice in Malawi. *Journal of Peasant Studies*. Accepted for publication August 20, 2018.

Bezner Kerr, R., E. Chilanga, H. Nyantakyi-Frimpong, I. Luginaah, E. Lupafya. 2016. Integrated agriculture programs to address malnutrition in northern Malawi. 2016. *BMC Public Health*, 16(1): 1197. Doi:10.1186/s12889-016-3840-0 Open access: http://rdcu.be/y81w.

Bezner Kerr, R., H. Nyantakyi-Frimpong, L. Dakishoni, E. Lupafya, L. Shumba, I. Luginaah, S. S. Snapp. 2018. Knowledge politics in participatory climate change adaptation research on agroecology in Malawi. *Renewal Agriculture and Food Systems*, doi.10.1017/S1742170518000017.

Bezner Kerr, R., Hickey, C., Lupafya, E. & Dakishoni, L. 2018. Repairing Rifts or Reproducing Inequalities? Agroecology, Food Sovereignty, and Gender Justice in Malawi. *Journal of Peasant Studies*. Accepted for publication August 20, 2018.

Bezner Kerr, R., L. Shumba, L. Dakishoni, E. Lupafya, P.R. Berti, L. Classen, S.S. Snapp, and M. Katundu. 2013. *Participatory, Agroecological and Gender-Sensitive Approaches to Improved Nutrition: A Case Study in Malawi*. Invited submission to the FAO Expert Meeting in November 2013, ‘Nutrition-Sensitive Food and Agriculture Systems’ in preparation for ICN+21. http://www.fao.org/food/nutritional-policies-strategies/icn2/expert-papers

Bezner Kerr, R., S.S. Snapp, M. Chirwa, L. Shumba and R. Msachi. 2007. Participatory Research on Legume Diversification with Malawian Smallholder Farmers for Improved Human Nutrition and Soil Fertility. *Experimental Agriculture* 43 (4): 1-17.

Bezner Kerr, R., Sera Young, Carrie Young, Vicky Santoso, Mufunanji Magalasi, Martin Entz, Esther Lupafya, Laifolo Dakishoni, Vicki Morrone, David Wolfe and Sieglinde S. Snapp. 2018. Farming for change: Development of a farmer-engaged integrated agroecology, nutrition, climate change and social equity curriculum in Malawi and Tanzania, Revised and resubmitted to *Agriculture and Human Values* (AHUM-D-17-00097), July 9 2018.

Bezner Kerr, R., **Berti, P.R. and Shumba, L.** 2010. Effects of Participatory Agriculture and Nutrition project on Child Growth in Northern Malawi. *Public Health Nutrition* 14(8):1466-1472. doi:10.1017/S1368980010002545.

Bhardwaj, D., Ansari, M.W., Sahoo, R.K. & Tuteja, N. 2014. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microb Cell Fact, 13: 66.

Bhutta, Z.A., Das, J.K., Rizvi, A., Gaffey, M.F., Walker, N., Horton, S., Webb, P., Lartey, A.,Black, R.E., 2013. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? Lancet 382, 452–477. http://dx.doi.org/10.1016/S0140-6736(13)60996-4.

Binam, J. N., Place, F., Kalinganire, A., Hamade, S., Boureima, M., Tougiani, A., Dakouo, J., Mounkoro, B., Diaminatou, S., Badji, M., Diop, M., Babou, A. B., & Haglund, E. 2015. Effects of farmer managed natural regeneration on livelihoods in semi-arid West Africa. Environmental Economics and Policy Studies 4, 543–575. https://link.springer.com/article/10.1007/s10018-015-0107-4

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., ***et al.*** 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet,* 382(9890): 427–451.

Blue Skies. 2010. Making fruit happy. Blue Skies Sustainability Report 2008/2009. Pitsford, Northamptonshire, UK, Blue Skies Holdings. http://www.blueskies.com/happyfruit.pdf

Blue Skies. 2012. The JEE Report 2010–2011. Our blue print for a sustainable business. Pitsford, Northamptonshire, UK, Blue Skies Holdings. http://www.blueskies.com/jee.pdf

Bommarco, R., Kleijn, D. & Potts, S.G. 2012. Ecological intensification: harnessing ecosystem services for food security. Trends in Ecology and Evolution, 28(4) :230–238. doi: 10.1016/j.tree.2012.10.012

Bonneuil, C., Demeulenaere, E., Thomas, F., Joly, P.B., Allaire, G. & Goldringer, I. 2006. Innover autrement? La recherche agronomique face à l’avènement d’un nouveau régime de production et régulation des savoirs en génétique végétale, Courrier de l’Environnement de l’INRA, n°30, pp.29-52

Brookes, G. & Barfoot, P. 2017. Farm income and production impacts of using GM crop technology 1996–2015, *GM Crops & Food*, 8(3): 156–193.

Brown, S. & Getz, C. 2011. Farmworker Food Insecurity and the Production of Hunger in California. In Cultivating Food Justice: Race, Class, and Sustainability, ed. A. Alkon and J. Agyeman. Cambridge, MA: MIT Press.

Bruckner, T. (2016). Agricultural Subsidies and Farm Consolidation. *American Journal of Economics and Sociology*, *75*(3), 623–648. https://doi.org/10.1111/ajes.12151. **Dorward, A. and E. Chirwa.** 2013. *Agricultural Subsidies: the recent Malawian experience*. Oxford, Oxford University Press.

Brussaard, L., Caron, P., Campbell, B., Lipper, L., Mainka, S., Rabbinge, R., Babin, D. & Pulleman, M. 2010. Reconciling biodiversity conservation and food security: scientific challenges for a new agriculture. Current Opinion on Environmental Sustainability, 2(1–2): 34–42. doi: 10.1016/j.cosust.2010.03.007.

Burity, V., Franceschini, T. & Valente, F., *et al.* 2010. Direito Humano à Alimentação Adequada no Contexto da Segurança Alimentar e Nutricional. Brasília, DF: ABRANDH, 2010. 204p.

Cakmak, I. & Kutman, U.B. 2018. Agronomic biofortification of cereals with zinc: a review. European Journal of Soil Science, 69(1): 172–180.

Campbell *et al.,* 2018

Campbell, B. M., Beare, D.J., Bennett, E. M.,Hall-Spencer, J. M.,Ingram, J. S. I.,Jaramillo, F., Ortiz, R., Ramankutty, N., Sayer, J. A. & Shindell, D. 2017. Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecology and Society, 22(4).

Cardinale, B.J., Wright, J.P., Cadotte, M.W., Carroll, I.T., Hector, A., Srivastava, D.S., Loreau, M., Weis, J.J., 2007. Impacts of plant diversity on biomass production increase through time because of species complementarity. Proc. Natl. Acad. Sci. U.S.A. 104, 18123–18128. doi:10.1073/pnas.070906910

Carletto, G., Zezza, A. & Banerjee, R. 2012. Towards better measurement of household food security: Harmonizing indicators and the role of household surveys. *Global Food Security,* 2(1): 30–40.

Caron, P., Ferrero y de Loma-Osorio, G., Nabarro, D., Hainzelin, E., Guillou, M., Andersen, I., Arnold, T., Astralaga, M., Beukeboom, M., Bickersteth, S., Bwalya, M, Caballero, P., Campbell, B.M., Divine, N., Fan, S., Frick, M., Friis, A., Gallagher, M., Halkin, J-P., Hanson, C., Lasbennes, F., Ribera, T., Rockstrom, J., Schuepbach, M. Steer, A., Tutwiler, A. & Verburg, G. 2018. Food systems for sustainable development: proposals for a profound four-part transformation. Agron. Sustain. Dev. 38: 41. https://doi.org/10.1007/s13593-018-0519-1

Carro-Ripalda S, Astier M (2014) Silenced voices, vital argument: smallholder farmers in the Mexican GM maize controversy. Agric Hum Values 31:655–663.

Carson, R. 1962. *Silent spring.* New York and Boston, USA, Houghton Mifflin.

Carswell, G. 1997. Agricultural intensification and rural sustainable livelihoods: a 'think piece'. Institute of Development Studies, Brighton.

Cartel, M., Smale, M. & Zambrano, P. 2006. Bales and balance. A review of the methods used to assess the economic impact of Bt cotton on farmers in developing economies, *AgBioForum,* 9(3): 195–212.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J. & Mitchell, R.B. 2003. Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14): 8086–8091. https://doi.org/10.1073/pnas.1231332100

Cassman, K.G. 1999. Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture. Proc Natl Acad Sci, 96(11):5952–5959.

Cassman, K.G. 2005. Ecological intensification of agriculture and implicationsfor improved water and nutrient management. In: Imas, P., Price, R. (eds) Fertigation: optimizing the utilization of water andnutrients. International Symposium on Fertigation, Beijing, China, 20–24 September 2005. International Potash Institute, Horgen, Switzerland, pp 23–34.

Cerdan, C.R., Rebolledo, M.C., Soto, G., Rapidel, B. & Sinclair, F.L. 2012. Local knowledge of impacts of tree cover on ecosystem services in smallholder coffee production systems. Agricultural Systems 110: 119-130 http://www.sciencedirect.com/science/article/pii/S0308521X12000571

Chambers, R. 1980. Understanding professionals: small farmers and scientists. IADS occasional papers. New York6 pp.

Chambers, R. 2017. *Can We Know Better?* Rugby, Practical Action Publishing. 194 pp.

Chomba, S.W., Nathan, I., Minang, P.A. & Sinclair, F.L. 2015. Illusions of empowerment? Questioning policy and practice of community forestry in Kenya. Ecology and Society **20**(3):2 https://www.ecologyandsociety.org/vol20/iss3/art2/

Christos and Eleftherohorinos, 2011

CIDSE (Coopération Internationale pour le Développement et la Solidarité). 2018. *The principles of agroecology. Towards just, resilient and sustainable food systems.* 11 p. https://www.cidse.org/publications/just-food/food-and-climate/the-principles-of-agroecology.html.

CIRAD (Centre de coopération internationale en recherche agronomique pour le développement). 2008. CIRAD Strategic Vision 2008–2012. www.cirad.fr/en/content/download/970/31343/version/6/file/CIRAD_Strategie_GB_web.pdf.

Claeys, P. 2015. Human Rights and the Food Sovereignty Movement: Reclaiming Control (Oxford and New York: Routledge.

Clark, W.C., Tomich, T.P., van Noordwijk, M., Guston, D., Catacutan, D., Dickson, N.M. & McNie, E. 2016. Boundary work for sustainable development: Natural resource management at the Consultative Group on International Agricultural Research (CGIAR). *Proceedings of the National Academy of Sciences*, 113(17): 4615–4622. https://doi.org/10.1073/pnas.0900231108

Coe, R., Njoloma, J. & Sinclair, F.L. 2016. Loading the dice in favour of the farmer: reducing the risk of adopting agronomic innovations. Experimental Agriculture. doi: http://dx.doi.org/10.1017/S0014479716000181

Coe, R., Njoloma, J., & Sinclair, F. (2016). Loading the dice in favour of the farmer: reducing the risk of adopting agronomic innovations. Experimental Agriculture, 1-17. doi:10.1017/S0014479716000181

Collins, P. H. (2000). Black feminist thought: Knowledge, consciousness, and the politics of empowerment (2nd ed.). NY: Routledge.

Comstock, G. 2014. Ethics and Genetically Modified Foods. In: Sandler R.L. (eds) Ethics and Emerging Technologies. Palgrave Macmillan, London pp. 473-485.

Consea. 2017. Apresentação [WWW Document]. Cons. Nac. Segur. Aliment. E Nutr. URL http://www4.planalto.gov.br/consea/acesso-a-informacao/institucional/apresentacao (accessed 1.31.17).

Conway, G.R. 1987. The properties of agroecosystems. *Agricultural Systems*, 24: 95–117.

CPDA (Christian Partners Development Agency). 2008. Report on the small-scale tea sector in Kenya. Nairobi, http://somo.nl/publications-en/Publication_3097

Crossland, M., Winowiecki, L., Pagella, T., Hadgu, K. & Sinclair, F.L. 2018. Implications of variation in local perception of degradation and restoration processes for implementing Land Degradation Neutrality. Environmental Development (in press).

Crowder, D.W., & Reganold, J.P. 2015. Financial competitiveness of organic agriculture on a global scale. Proc., Natl., Acad., Sci., USA, 112(24): 7611–7616. doi: 10.1073/pnas.1423674112.

Crowley, M. & Roscigno, V. 2004. Farm concentration, political economic process and strategification: the case of North Central US. *Journal of Political and Military Sociology* 31: 133-55

Crowley, M. and V. Roscigno. 2004. Farm concentration, political economic process and stratification: the case of North Central US. *Journal of Political and Military Sociology* 31: 133-55;

Crowley, M. and V. Roscigno. 2004. Farm concentration, political economic process and stratification: the case of North Central US. *Journal of Political and Military Sociology* 31: 133-55

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2017. Food and Agribusiness, A Roadmap for unlocking value-added growth opportunities for Australia.

Cunningham K, Ruel M, Ferguson E, Uauy R. 2015 Women's empowerment and child nutritional status in South Asia: a synthesis of the literature. Matern Child Nutr. 11:1–19.

D. Catacutan, C. Muller, M. Johnson, D. Garrity. 2015. Landcare – A landscape approach at scale. P.A. Minang, *et al.* (Eds.), Climate-smart landscapes: Multifunctionality in practice, WAC/ICRAF, Nairobi (2015), pp. 151-160

Dalgaard, T., Hutchings, N.J. & Porter, J.R. 2003. Agroecology, scaling and interdisciplinarity. *Agriculture, Ecosystems and Environment* 100 (2003): 39-51.

Dania, W.A.P., Xing, K. & Amer, Y. 2018. Collaboration behavioural factors for sustainable agri-food supply chains: A systematic review. Journal of Cleaner Prod., 186: 851–864.

Davis, K. 2008. "Intersectionality as Buzzword: A Social Science Perspective on What Makes a Feminist Theory Successful." Feminist Theory 9 (1): 67–86.

Dawson IK, Place P, Torquebiau E, Malézieux E, Iiyama M, Sileshi GW, Kehlenbeck K, Masters E, McMullin S and Jamnadas R. 2013. Agroforestry, food and nutritional security. Background paper for the International Conference on Forests for Food Security and Nutrition, FAO, Rome, 13–15 May, 2013. http://www.fao.org/forestry/37082-04957fe26afbc90d1e9c0356c48185295.pdf

De Longe, M.S., Miles, A. & Carlisle, L. 2016. Investing in the transition to sustainable agriculture. Environmental Science & Policy 55(2016): 266–273. https://core.ac.uk/download/pdf/82089420.pdf

de Molina, M.G. 2013. Agroecology and politics. How to get sustainability? About the necessity for a political agroecology. *Agroecology and Sustainable Food Systems,* 37 (1): 45-59.

de Ponti, T., Rijk, B., & van Ittersum, M.K. 2012. The crop yield gap between organic and conventional agriculture. Agricultural Systems, 108: 1–9.

De Silva *et al.,* 2006

De Steur, H., Gellynck, X., Van Der Straeten, D., Lambert, W., Blancquaert, D., *et al.* 2012. Potential impact and cost-effectiveness of multi-biofortified rice in China. *New Biotechnology,* 29: 432–442.

DeFries, R., Fanzo, J., Remans, R., Palm, C., Wood, S. and Anderman, T.L. 2015. Metrics for land-scarce agriculture. Science, 349, 238–240.

DeFries, R., Fanzo, J., Remans, R., Palm, C., Wood, S. Anderman, T.L. 2015. Global nutrition metrics for land-scarce agriculture. Science, 349 (6245): 238–240.

Dehnen-Schmutz, K., Foster, G.L., Owen, L. *et al.* Agron. Sustain. Dev. (2016) 36: 25. https://doi.org/10.1007/s13593-016-0359-9

DeLonge, M. S., Miles, A., & Carlisle, L. (2016). Investing in the transition to sustainable agriculture. *Environmental Science & Policy*, *55*, 266–273.https://doi.org/10.1016/j.envsci.2015.09.013

DeLonge, M. S., Miles, A., & Carlisle, L. (2016). Investing in the transition to sustainable agriculture. *Environmental Science & Policy*, *55*, 266–273.https://doi.org/10.1016/j.envsci.2015.09.013

DFID (UK Department for International Development). 2014. Can Agriculture Interventions Promote Nutrition? Agriculture and Nutrition Evidence Paper. London UK.

Diaz, R., & Rosenberg, R. 2008. Spreading dead zones and consequences for marine ecosystems. Science, 321(5891), 926-929.

Dinesh D. (Ed.). 2016. Agricultural practices and technologies to enhance food security, resilience and productivity in a sustainable manner: Messages to SBSTA 44 agriculture workshops. CCAFS Working Paper no. 146. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). http://hdl.handle.net/10568/71050

Dixon, H.J., Doores, J.W., Joshi, L. & Sinclair, F.L. 2001. *Agroecological Knowledge Toolkit for windows: Methodological guidelines, computer software and manual for AKT5*. Bangor, University of Wales. 181 pp.

Domènech, L. 2015. Improving irrigation access to combat food insecurity and undernutrition: a review. Glob., Food Secur., 6: 24–33. http://dx.doi.org/10.1016/j.gfs.2015.09.001.

Donham, K., S. Wing, D. Osterberg, J. Flora, C. Hodne, K. Thu and P. Thorne. 2007. Community health and socioeconomic issues surrounding animal feeding operations. *Environmental Health Perspectives* 115(2): 317-20;

Donham, K., S. Wing, D. Osterberg, J. Flora, C. Hodne, K. Thu and P. Thorne. 2007. Community health and socioeconomic issues surrounding animal feeding operations. *Environmental Health Perspectives* 115(2): 317-20

Doré, T., Makowski, D., Malézieux, E., Munier-Jolain, N., Tchamitchian, M. & Tittonell, P. 2011. Facing up to the paradigm of ecological intensification in agronomy: revisiting methods, concepts and knowledge. European Journal of Agronomy, 34:197–210. doi: 10.1016/j.eja.2011.02.006.

Dorin, B. 2017. India and Africa in the Global Agricultural System (1961-2050): Towards a New Sociotechnical Regime. Review of Rural Affairs, Vol LII (25&26): 5–13.

Duguma LA, Minang PA, Freeman OE and Hagar H (2014). System wide impacts of fuel usage patterns in the Ethiopian highlands: potentials for breaking the negative reinforcing feedback cycles. Energy for Sustainable Development 20 (2014) 77–85

Dumont S.E., Bonhomme, S., Pagella, T. & Sinclair, F.L. 2017. Structured stakeholder engagement leads to the development of more diverse and inclusive agroforestry options. Experimental Agriculture (online) https://www.cambridge.org/core/journals/experimental-agriculture/article/div-classtitlestructured-stakeholder-engagement-leads-to-development-of-more-diverse-and-inclusive-agroforestry-optionsdiv/9DC532BE3248808F9D9EFA14D02D4CAC

Dumont, A.M., Vanloqueren, G., Stassart, P.M. & Baret, P.V. 2016. Clarifying the socioeconomic dimensions of agroecology: between principles and practices. *Agroecology and Sustainable Food Systems,* 40(1): 24–47. DOI: 10.1080/21683565.2015.1089967

Dumont, B., Fortun-Lamothe, L., Jouven, M., Thomas, M. & Tichit, M. 2013. Prospects from agroecology and industrial ecology for animal production in the 21st century. *Animal*, 7(6): 1028–1043.

Engle, P.L., Black, M.M., Behrman, J.R., Cabral de Mello, M., Gertler, P.J. & Kapiriri, L. 2007. Strategies to avoid the loss of developmental potential in more than 200 million children in the developing world. Lancet, 369: 229–242.

Engle, P.L., Fernald, L.C.H., Alderman, H., *et al.* 2011. Strategies for reducing inequalities and improving developmental outcomes for young children in low-income and middle-income countries. Lancet, 378: 1339–

Etkin, N.L. 2011. Edible medicines: An ethnopharmacology of food: *Journal of Agricultural and Environmental Ethics*, *24*(1): 91–99. https://doi.org/10.1007/s10806-010-9244-8

Fairbairn, M. (2012). Framing transformation: the counter-hegemonic potential of food sovereignty in the US context. Agriculture and Human Values, 29(2), 217–230. https://doi.org/10.1007/s10460-011-9334-x

FAO & INRA (Institut National de la Recherche Agronomique). 2016. Innovative markets for sustainable agriculture: How innovations in market institutions encourage sustainable agriculture in developing countries. Rome, FAO.

FAO (2014). Developing sustainable food value chains – Guiding principles. FAO, Rome.

FAO (Food and Agriculture Organization of the United Nations). 1996. Rome Declaration on World Food Security. World Food Summit, Rome.

FAO (Food and Agriculture Organization of the United Nations). 2002. *Conservation and adaptive management of globally important agricultural heritage systems (GIAHS).* Global Environment Facility, Project Concept Note. Rome.

FAO 2014. Nutrition Sensitive Agriculture. Briefing for Second International Conference on Nutrition. http://www.fao.org/about/meetings/icn2/preparations/document-detail/en/c/238665/.

FAO 2017. *Agroecology Knowledge Hub. Agroecology definitions*. http://www.fao.org/agroecology/knowledge/definitions/en/?page=1&ipp=6&no_cache=1&tx_dynalist_pi1[par]=YToxOntzOjE6IkwiO3M6MToiMCI7fQ (accessed on April 2018).

FAO, IFAD, UNICEF, WFP and WHO. 2018. The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Rome, FAO. http://www.fao.org/3/I9553EN/i9553en.pdf

FAO, IFAD, WFP, 2017. State of Food Insecurity in the World. Rome, FAO.

FAO. (in publication). Farmers working together, working with researchers: Scoping study on farmer research networks for Agroecology. Rome.

FAO. 2006. “Food Security.” FAO Policy Briefs 2. Rome: FAO. http://www.fao.org/forestry/13128-0e6f36f27e0091055bec28ebe830f46b3.pdf

FAO. 2009 Organic agriculture: glossary on organic agriculture. Rome. 173 p. http://www.fao.org/tempref/docrep/fao/012/k4987t/k4987t.pdf.

FAO. 2009. The potato supply chain to PepsiCo’s Frito Lay in India, by M. Punjabi.

FAO. 2010. Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Rome, Italy.

FAO. 2011. *Save and grow: a policy maker’s guide to the sustainable intensification of smallholder crop production.* Rome. 116 p. http://www.fao.org/docrep/014/i2215e/i2215e.pdf

FAO. 2013. Making Kenya's efficient tea markets more inclusive. MAFAP Policy Brief #5. Rome. http://www.fao.org/docrep/018/aq657e/aq657e.pdf

FAO. 2013. Organic agriculture: African experiences in resilience and sustainability, edited by R. Auerbach, G. Rundgren & N. El-Hage Scialabba. Rome.

FAO. 2013. The State of Food and Agriculture (SOFA). Food Systems for Better Nutrition. FAO, Rome, Italy.

FAO. 2014. Developing sustainable food value chains – Guiding principles. Rome.

FAO. 2014. *The State of Food and Agriculture. Innovation in family farming.* Rome. 161p. http://www.fao.org/3/a-i4040e.pdf

FAO. 2015. *Agroecology for food security and nutrition. Proceedings of the FAO international symposium.* 18–19 September 2014. Rome. http://www.fao.org/3/a-i4729e.pdf

FAO. 2015. *Final report for the international symposium on agroecology for food security and nutrition.* 18–19 September 2014. Rome. http://www.fao.org/3/a-i4327e.pdf

FAO. 2015. *The State of Food Insecurity and Nutrition*. Rome, FAO

FAO. 2016. *Achieving sustainable rural development through agricultural innovation.* COAG 25th Session. 26–30 September 2016. COAG/2016/6. Rome. http://www.fao.org/3/a-mr236e.pdf

FAO. 2016. *Outcomes of the international symposium and regional meetings on agroecology for food security and nutrition.* COAG 25th Session, 26–30 September 2016. COAG 2016/INF/4. Rome. http://www.fao.org/3/a-mr319e.pdf

FAO. 2016. *The Globally Important Agricultural Heritage Systems (GIAHS).* COAG 25th Session. 26–30 September 2016. COAG/2016/11. Rome. http://www.fao.org/3/a-mr240e.pdf

FAO. 2017. *Strategic work of FAO to reduce rural poverty.* Rome http://www.fao.org/3/a-i6835e.pdf

FAO. 2017. *The future of food and agriculture. Trends and challenges*. Rome. http://www.fao.org/3/a-i6583e.pdf

FAO. 2017. *The State of Food Insecurity and Nutrition*. Rome, FAO

FAO. 2018. *Agroecology Knowledge Hub. 10 elements.* http://www.fao.org/agroecology/knowledge/10-elements.

FAO. 2018. Agroecology Knowledge Hub. 10 elements. http://www.fao.org/agroecology/knowledge/10-elements.

FAO. 2018. *Catalysing dialogue and cooperation to scale up agroecology: outcomes of the FAO regional seminars on agroecology.* Rome. http://www.fao.org/3/I8992EN/i8992en.pdf

FAO. 2018. FAO's work on agroecology. A pathway to achieving the SDGs. 27 p., http://www.fao.org/3/i9021en/I9021EN.pdf

FAO. COAG 2016/INF/4. *Outcomes of the international symposium and regional meetings on agroecology for food security and nutrition.* COAG 25th Session, 26-30 September 2016. Rome. http://www.fao.org/3/a-mr319e.pdf

Ferguson, R.S. & Lovell, S.T. 2014. "Permaculture for Agroecology: Design, Movement, Practice, and Worldview. A Review." Agronomy for Sustainable Development. https://doi.org/10.1007/s13593-013-0181-6.

Ferguson, R.S. & Lovell, S.T. 2015. Grassroots Engagement with Transition to Sustainability: Diversity and Modes of Participation in the International Permaculture Movement. Ecology and Society, 20(4): 39. https://doi.org/10.5751/ES-08048-200439.

Finkelstein, J. L., Haas, J. D., & Mehta, S. (2017). Iron-biofortified staple food crops for improving iron status: a review of the current evidence. Current Opinion in Biotechnology, 44, 138–145. https://doi.org/10.1016/j.copbio.2017.01.003

Fiorella, K.J., Chen, R.L., Milner, E.M. & Fernald, L.C.H. 2016. Agricultural interventions for improved nutrition: a review of livelihood and environmental dimensions. Glob. Food Secur., 8: 39–47. http://dx.doi.org/10.1016/j.gfs.2016.03.003.

Firbank, L.G., Elliott, J., Drake, B., Cao, Y. & Gooday, R. 2013. Evidence of sustainable intensification among British farms. Agriculture Ecosystems and Environment, 173: 58–65. doi:10.1016/j.agee.2013.04.010.

Flavell, R. 2010. Knowledge and technologies for sustainable intensification of food production. New Biotechnol, 27(5): 505–516.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.F., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D. & Zaks, D.P.M. 2011. Solutions for a cultivated planet. *Nature,* 478: 337–342.

Foltz, J. and K. Zueli 2005. The role of community and farm characteristics on farm input purchasing patterns. *Review of Agricultural Economics* 27: 508-25

Forster D, Adamtey N, Messmer MM, Pfiffner L, Baker B, Huber B, Niggli U. 2013. Organic agriculture - driving innovations in crop research. Agricultural Sustainability. http://dx.doi.org/10.1016/B978-0-12-404560-6.00002-2

Francis, C. Wiedenhoeft, M., Dehaan, R. & Porter, P. 2017. Education in Agroecological Learning: Holistic Context for Learning Farming and Food Systems. In: Wezel, A. (Ed.), Agroecological practices for sustainable agriculture: principles, applications, and making the transition. World Scientific, New Jersey, USA, pp. 395-418.

Francis, C., Lieblein, G., Gliessman, S., Breland, T.A., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D., Salvador, R., Wiedenhoeft, M., Simmons, S., Allen, P., Altieri, M., Flora, C. & Poincelot, R. 2003. Agroecology: the ecology of food systems. *Journal of Sustainable Agriculture*, 22(3): 99–118. http://dx.doi.org/10.1300/J064v22n03_10

Francis, C.A., Jordan, N., Porter, P., Breland, T.A., Lieblein, G., Salomonsson, L., Sriskandarajah, N., Wiedenhoeft, M., DeHaan, R., Braden, I. & Langer. V. 2011. Innovative education in agroecology: experiential learning for a sustainable agriculture. *CRC Critical Reviews in Plant Science* 30(1&2), 226-237.

Franzel S., Carsan S, Lukuyu B and Wambugu C (2014). Fodder trees for improving livestock productivity and smallholder livelihoods in Africa. Current Opinion in Environmental Sustainability, 6: 98-103 https://www.sciencedirect.com/science/article/pii/S1877343513001565

Friederichs K. 1930. Die Grundfragen und Gesetzmäßigkeiten der landund forstwirtschaftlichen Zoologie. Vol. 1: Ökologischer Teil, Vol. 2: Wirtschaftlicher Teil. Berlin, Germany, Verlagsbuchhandlung Paul Parey. 417 and 443p.

FTA. 2017. Livelihood Systems Flagship. CGIAR Research Programme on Forests, Trees and Agroforestry pp 81-118. http://foreststreesagroforestry.org/wp-content/uploads/pdf/2FTA-CRPandFPNarrativesProposal2017-2022.pdf

Garbach, K, Milder, J.C., DeClerck, F.A.J., Montenegro, M., Driscoll, L. & Gemmill-Herren, B. 2017. Examining multi-functionality for crop yield and ecosystem services in five systems of agroecological intensification, International Journal of Agricultural Sustainability, 15:1, 11-28, DOI: 10.1080/14735903.2016.1174810

Garibaldi, L.A., Carvalheiro, L.G., Vaissière, B.E., Gemmill-Herren, B., Hipólito, J., Freitas, B.M., Ngo, H.T., Azzu, N., Sáez, A., Åström, J. & An, J. 2016. Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science*, 351(6271): 388–391.

Garibaldi, L.A., Carvalheiro, L.G., Vaissière, B.E., Gemmill-Herren, B., Hipólito, J., Freitas, B.M., Ngo, H.T., Azzu, N., Sáez, A., Åström, J., An, J., Blochtein, B., Buchori, D., Chamorro García, F.J., Oliveira Da Silva, F., Devkota, K., De Fátima Ribeiro, M., Freitas, L., Gaglianone, M.C., Goss, M., Irshad, M., Kasina, M., Pacheco Filho, A.J.S., Piedade Kiill, L.H., Kwapong, P., Nates Parra, G., Pires, C., Pires, V., Rawal, R.S., Rizali, A., Saraiva, A.M., Veldtman, R.,Viana, B.F., Witter S., & Zhang, H. 2016. Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science*. **351**, 388–391 (2016). http://science.sciencemag.org/content/sci/351/6271/388.full.pdf

Garnett, T. & Godfray, C. 2012. *Sustainable intensification in agriculture, navigating a course through competing food system priorities*. Food Climate Research Network and the Oxford Martin Programme on the Future of Food, University of Oxford, UK.

Garnett, T., Appleby, M.C., Balmford, A., Bateman, I.J., Benton, T.G., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., Herrero, M., Hoffmann, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J. & Godfray, H.C.J. 2013. Sustainable intensification in agriculture: premises and policies. Science, 341(6141): 33–34. doi:10.1126/science. 1234485.

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., Mäder, P., Stolze, M., Smith, P., Scialabba, Nel-H. & Niggli, U. 2012. Enhanced top soil carbon stocks under organic farming. Proc., Natl., Acad., Sci., USA, 109(44): 18226–18231. doi: 10.1073/pnas.1209429109.

Gilbert, N. 2013. A hard look at GM crops. *Nature,* 497: 24–26.

Giller, K.E., Tittonell, P., Rufino, M.C., van Wijk, M.T., Zingore, S., Mapfumo, P. *et al.* 2011. Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. Agricultural Systems, 104(2): 191–203.

GIZ. 2011. Financing agricultural value chains in Africa – a synthesis of four country case studies. Bonn, Germany.

Gkisakis *et al.*, 2017

Gliessman S.R. 2007. *Agroecology: the ecology of sustainable food systems.*CRC Press, Taylor & Francis, New York, USA. 384 p.

Gliessman, 1990

Gliessman, 2018

Gliessman, S.R. 1997. *Agroecology: ecological processes in sustainable agriculture*. New York, USA, CRC Press, Taylor and Francis.

Gliessman, S.R. 2007. *Agroecology: the ecology of sustainable food systems.* New York, USA, CRC Press, Taylor & Francis. 384 p. (3rd edition 2015).

GloPan (Global Panel on Agriculture and Food Systems for Nutrition). 2016. *Food systems and diets: facing the challenges of the 21st century.* Foresight Report. London, UK. https://www.glopan.org/sites/default/files/Downloads/Foresight%20Report.pdf

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. & Toulmin, C. 2010. Food security: the challenge of feeding 9 billion people. Science, 327(5967):812–818. doi:10.1126/science.1185383.

Goicoechea, N. & Antolin, M.C. 2017. Increased nutritional value in food crops. Microbial biotechnology, 10(5): 1004–1007.

Gómez, M.I., Barrett, C.B., Raney, T., Pinstrup-Andersen, P., Meerman, J., Croppenstedt, A., Carisma, B. & Thompson, B. 2013. Post-green revolution food systems and the triple burden of malnutrition. *Food Policy*, 42: 129-138. doi:10.1016/j.foodpol.2013.06.009

Gomiero, T., Pimental, D. & Paoletti, M.G. 2011. Is there a need for a more sustainable agriculture?. *Critical reviews in plant sciences* 30 (1-2): 6-23.

Gonzalez de Molina, 2013;

Goulson, 2014

Graeub, B.E., Chappell, M.J., Wittman, H., Ledermann, S., Bezner Kerr R. & Gemmill-Herren, B. 2016. The state of family farms in the world. World Development 87: 1–15 doi.org/10.1016/j.worlddev.2015.05.012.

Graeub, B.E., M.J. Chappell, H. Wittman, S. Ledermann, R. Bezner Kerr and B. Gemmill-Herren. 2016. The state of family farms in the world. *World Development* 87:1-15 doi.org/10.1016/j.worlddev.2015.05.012

Gustavsson, J., Cederberg, C. Sonesson, U. 2011. Global Food Losses and Food Waste, Study conducted for the International Congress. Rome, FAO.

Gutierrez, A. P., Ponti, L., Herren, H. R., Baumgärtner, J., & Kenmore, P. E. (2015). Deconstructing Indian cotton: weather, yields, and suicides. *Environmental Sciences Europe*, *27*(1). https://doi.org/10.1186/s12302-015-0043-8.

Guzmán, E.S. & Woodgate, G. 2013. Agroecología: Fundamentos Del Pensamiento Social Agrario y Teoría Sociológica. Agroecología, 8(2).

Haddad, L., Pena, C., Nishida, C., *et al.* 1996. *Food Security and Nutrition Implications of Intrahousehold Bias: A Review of Literature.* FCND Discussion Paper no. 19. Washington, DC: International Food Policy Research Institute.

Halloran, A., Clement, J., Kornum, N., Bucatariu, C. & Magid, J. 2014. Addressing food waste reduction in Denmark. Food Policy, 49: 294–301.

Hammond, B.G., Vicini, J.L., Hartnell, G.F., Naylor, M.W., Knight, C.D., Robinson, E.H., Fuchs, R.L. & Padgette, S.R. 1996. The feeding value of soybeans fed to rats, chickens, catfish and dairy cattle is not altered by genetic incorporation of glyphosate tolerance. *J Nutr.,* 126: 717–727.

Hayami, Y. & Ruttan, V.W. 1985. *Agricultural Development, An International Perspective*. Baltimore and London: Johns Hopkins University Press, 2nd edition.

Hebinck, P., S. Schneider, and J. D. Van Der Ploeg. 2014. Rural development and the construction of new markets, vol. 12. London: Routledge.

Helmers, M.J., Zhou, X., Asbjornsen, H., Kolka, R., Tomer, M.D. & Cruse, R.M. 2012. Sediment removal by prairie filter strips in row-cropped ephemeral watersheds. J Environ Qual 41: 1531–1539. doi: 10.2134/jeq2011.0473.

Herrero, M., Thornton, P.K., Power, B., Bogard, J.R., Remans, R., Fritz, S., Gerber, J.S., Nelson, G., See, L., Waha, K. & Watson, R.A. 2017. Farming and the geography of nutrient production for human use: a transdisciplinary analysis. *The Lancet Planetary Health*, 1(1), e33-e42.

Hertel, T.W. 2015. The challenges of sustainably feeding a growing planet. Food Security 7 (2) 185-198.

High Level Panel of Experts on Food Security and Nutrition (HLPE) 2012. Social Protection for Food Security. FAO, Rome, Italy.

Hislop, R. 2014.'Reaping Equity Across the USA: FJ Organizations Observed at the National Scale. MA thesis. University of California–Davis.

HLPE 2015. Water for Food Security and Nutrition. FAO, Rome, Italy.

HLPE. 2014. Food Losses and Waste in the Context of Sustainable Food Systems. FAO, Rome. http://www.fao.org/3/a-i3901e.pdf

HLPE. 2014. Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2014. http://www.fao.org/3/a-i3901e.pdf

HLPE. 2016. *Sustainable agricultural development for food security and nutrition: what roles for livestock?* A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome. http://www.fao.org/3/a-i5795e.pdf

HLPE. 2016. *Sustainable agricultural development for food security and nutrition: what roles for livestock?* A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome. http://www.fao.org/3/a-i5795e.pdf

HLPE. 2017. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. http://www.fao.org/3/a-i7846e.pdf

HLPE. 2017. *Sustainable forestry for food security and nutrition.* A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. http://www.fao.org/3/a-i7395e.pdf

Hobbs, P.R., Sayre, K. & Gupta, R. 2008. The role of conservation agriculture in sustainable agriculture. Philos Trans R Soc Lond B Biol Sci. 363(1491): 543–555. doi: 10.1098/rstb.2007.2169

Hokkanen and Menzler-Hokkanen, 2017

Holme *et al.*, 2016

Hotz, C., Loechl, C., Lubowa, A. *et al.* 2012. Introduction of beta-carotene-rich orange sweet potato in rural Uganda resulted in increased vitamin A intakes among children and women and improved vitamin A status among children. J. Nutr., 142 (10):1871–1880.

Hotz, C., Loechl, C., Lubowa, A., Tumwine, J.K., Ndeezi, G., Masawi, A.N., Baingana, R.,

Howard, P. 2016. Concentration and Power in the Food System. London/New York: Bloomsbury.

Howard, P.H. 2015. Intellectual Property and Consolidation in the Seed Industry. *Crop Science,* 55(6): 2489.

Hu *et al.*, 2016

Hwang, T., Ndolo, V. U., Katundu, M., Nyirenda, B., Bezner Kerr, R., Arntfield, S., & Beta, T. 2016. Provitamin A potential of landrace orange maize variety (*Zea mays L*.) grown in different geographical locations of central Malawi. *Food Chemistry, 196*: 1315–1324. doi:10.1016/j.foodchem.2015.10.067

IARC. 2018. *IARC response to criticisms of the Monographs and the glyphosate evaluation.* http://www.iarc.fr/en/media-centre/iarcnews/pdf/IARC_response_to_criticisms_of_the_Monographs_and_the_glyphosate_evaluation.pdf.

Icowitz, A., Powell, B., Salim, M. & Sunderland, T. 2014. Dietary quality and tree cover in Africa. Global Environmental Change 24: 287-294 https://www.sciencedirect.com/science/article/pii/S0959378013002318

Ilstedt U., Bargués Tobella, A. Bazié, H.R., Bayala, J., Verbeeten, E., Nyberg, G., Sanou, J., Benagas, L., Murdiyarso, D., Laudon, H., Sheil, D. & Malmer, A. 2016. Intermediate tree cover can maximize groundwater recharge in the seasonally dry tropics. Nature Scientific Reports 6, Article number: 21930 https://www.nature.com/articles/srep21930

International Institute for Environment and Development (IIED). 2018. *Biocultural innovation: the key to global food security?* Briefing paper, http://pubs.iied.org/17465IIED/

IPCC, 2014

IPES-Food. 2016. *From university to diversity. A paradigm shift from industrial agriculture to diversified agroecological systems.* International Panel of Experts on Sustainable Food Systems. http://www.ipes-food.org/images/Reports/UniformityToDiversity_FullReport.pdf

Irani, Z., Sharif, A.M., Lee, H., Aktas, E., Topaloğlu, Z., van't Wout, T., Huda, S. 2018 Managing food security through food waste and loss: Small data to big data. Computers and Operations Research 98: 367-383

IRDC (International Research and Development Corp). 1998. *Alliance for biointegrity.* http://www.biointegrity.org including Calgene FLAVR SAVR™ tomato report, pp 1–604;. first test report, pp 1736–1738; Conclusions of the expert panel regarding the safety of the FLAVR SAVR™ tomato, ENVIRON, Arlington VA, USA pp 2355–2382; Four week oral (intubation) toxicity study in rats by IRDC, pp 2895–3000.

IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development). 2009. *Agriculture at a crossroads: global report.* B.D. MacIntyre, H.R. Herren, J. Wakhungu, R.T. Watson, eds. Washington, DC, Island Press.

IAASTD. 2008. Agriculture at a crossroads: global summary for decision makers.

Jackson. B,, Pagella, T., Sinclair, F., Orellana, B., Henshaw, A., Reynolds, B., McIntyre, N., Wheater, H. & Eycott, A. 2013. Polyscape: A GIS mapping toolbox providing efficient and spatially explicit landscape-scale evaluation of multiple ecosystem services. Landscape and Urban Planning 112: 74–8.

Jackson-Smith, D. and G. Gillespie. 2005. Impacts of farm structural change on farmers' social ties. *Society and Natural* Resources 18: 215-40.

James, C. 2012. Global Status of Commercialized Biotech/GM Crops, *ISAAA Briefs No.44* (International Service for the Acquisition of Agri-biotech Applications, Ithaca, NY.

Johns and Ezyaguirre, 2007

Johns, T., Powell, B., Maundu, P., Eyzaguirre, P.B., 2013. Agricultural biodiversity as a link between traditional food systems and contemporary development, social integrity and ecological health. J. Sci. Food Agric. 93, 3433–3442. doi:10.1002/jsfa.6351

Joly, P.-B. 2018. Innovation and the problem of values. Note de recherche 6, Institut Francilien Recherce Innovation Société (IFRIS).

Jones, A.D., Ickes, S.B., Smith, L.E., Mbuya, M.N.N., Chasekwa, B., Heidkamp, R.A., Menon, P., Zongrone, A.A., Stoltzfus, R.J. 2014. World Health Organization infant and young child feeding indicators and their associations with child anthropometry: a synthesis of recent findings: Associations of feeding indicators with growth. Maternal & Child Nutrition, 10(1), 1–17. https://doi.org/10.1111/mcn.12070

Jones, A.D., Shrinivas, A., Bezner Kerr, R., 2014. Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. Food Policy 46, 1–12. doi:10.1016/j.foodpol.2014.02.001

Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S., Lebailly, P. 2017. Organic farming and small-scale farmers: Main opportunities and challenges ecological economics. Vol 132, 144-154

Kabeer, N. 1999. Resources, agency, achievements: Reflections on the measurement of women's empowerment. Dev., Change. 30: 435–464.

Kahane, R., Hodgkin, T., Jaenicke, H., Hoogendoorn, C., Hermann, M., Keatinge, J.D.H., Hughes, J.D., Padulosi, S. & Looney, N. 2013. Agrobiodiversity for food security, health and income. *Agronomy for Sustainable Development,* 33(4): 671–693

Kamel *et al.,* 2003

Kangmennaang, J., R. Bezner Kerr, E. Lupafya, L. Dakishoni, M. Katundu, I. Luginaah. 2017. Impact of a participatory agroecological development project on household wealth and food security in Malawi. *Food Security* 9: 561-576. DOI 10.1007/s12571-017-0669-z.

Kangmennaang, J., R. Bezner Kerr, R., Lupafya, E., Dakishoni, L., Katundu, M. & Luginaahm I. 2017. Impact of a participatory agroecological development project on household wealth and food security in Malawi. *Food Security,* 9: 561–576. DOI 10.1007/s12571-017-0669-z

Keating, B.A., Herrero, M., Carberry, P. S., Gardner, J. & Cole, M. B. 2014. Food wedges: framing the global food demand and supply challenge towards 2050. *Global Food Security,* 3: 125–132.

Keding, G.B., Msuya, J.M., Maass, B.L. & Krawinkel, M.B. 2013. Obesity as a public health problem among adult women in rural Tanzania. *Global Health: Science and Practice,* 1(3): 359–371.

Khadse, Ashlesha, Peter Michael Rosset, Helda Morales & Bruce G. Ferguson. 2018. Taking agroecology to scale: the Zero Budget Natural Farming peasant movement in Karnataka, India, The Journal of Peasant Studies, 45:1, 192-219, DOI: 10.1080/03066150.2016.1276450 https://doi.org/10.1080/03066150.2016.1276450

Kilelu *et al.*, 2012

Kislev, Y. & Peterson, W. 1986. *Economies of scale in agriculture: a survey of the evidence*. Development Research Department discussion paper; no. DRD 203. Washington DC; World Bank.

Klages, K.H.W. 1942. *Ecological crop geography.* New York, USA, MacMillan. 615 p.

Kleemann, L. 2011. Organic pineapple farming in Ghana: A good choice for smallholders? (No. 1671). Kiel Working Papers. http://www.pegnet.ifwkiel.de/research/grants/results/kwp-1671.pdf

Klein, A.-M., Vaissiere, B., Cane, J., Steffan-Dewenter, I., Cunningham, S., Kremen, C., & Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops.Proceedings of the Royal Society B: Biological Sciences, 274(1608), 303-313.

Kovacs-Hostyanszki, A., Espindola, A., Vanbergen, A.J., Settele, J., Kremen, C. & Dicks, L.V. 2017. Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. *Ecology Letter*, 20(5): 673–689.

Kremen, C., Iles, A. & Bacon, C. 2012. Diversified Farming Systems: An Agroecological, Systems-based Alternative to Modern Industrial Agriculture. *Ecology and Society*, 17(4): 44.

Kumar, A. & Verma, J.P. 2018. Does plant-Microbe interaction confer stress tolerance in plants: A review? *Microbiological Research*, 207: 41–52.

Kumar, N., Harris, J., Rawat, R., 2015. If they grow it, will they eat and grow? Evidence from Zambia on agricultural diversity and child undernutrition. The Journal of Development Studies 51, 1060–1077. doi:10.1080/00220388.2015.1018901

Kumar, N., Nguyen, P. H., Harris, J., Harvey, D., Rawat, R., & Ruel, M. T. (2018). What it takes: evidence from a nutrition- and gender-sensitive agriculture intervention in rural Zambia. Journal of Development Effectiveness, 10(3), 341–372. https://doi.org/10.1080/19439342.2018.1478874

Kuyper T.W. & Struik P.C. 2014. Epilogue: Global food security, rhetoric, and the sustainable intensification debate. Current Opinion in Environmental Sustainability. 2014;8:71–79. doi: 10.1016/j.cosust.2014.09.004

La Via Campesina. 1996. Food sovereignty principles. www.viacampesina.org

Lachat, C., Ranieri, J.E., Walker Smith, K., *et al.* 2018. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. *Proc. Natl Acad. Sci*., 115: 127–132.

Langelaan, H.C., Pereira da Silva, F., Thoden van Velzen, U., Broeze, J., Matser, A.M., Vollebregt, M., Wageningen UR Food & Biobased Research. 2013. Technology options for feeding 10 billion people. Options for sustainable food processing. State of the art report. Science and Technology Options Assessment. Brussels: European Parliament. http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513533/IPOL-JOIN_ET(2013)513533_EN.pdf

Le Port, A., Bernard, T., Hidrobo, M., Birba, O., Rawat, R. & Ruel, M.T. 2017. Delivery of iron-fortified yoghurt, through a dairy value chain program, increases hemoglobin concentration among children 24 to 59 months old in Northern Senegal: a cluster randomized control trial. PLoS One, 12: 1–17. http://dx.doi.org/10.1371/journal.pone.0172198.

Lee, K.S., Choe, Y.C. & Park, S.H. 2015. Measuring the environmental effects of organic farming: A meta-analysis of structural variables in empirical research. Journal of Environmental Management, 162:263e274.

Leroy, J.L., Gadsden, P., De Cossío, T.G. & Gertler, P. 2013. Cash and in-kind transfers lead to excess weight gain in a population of women with a high prevalence of overweight in rural Mexico. J. Nutr., 143: 378–383

Leroy, J.L., Gadsden, P., Rodríguez-Ramírez, S. & Gonzalez de Cossio, T. 2010. Cash and in-kind transfers in poor rural communities in Mexico increase household fruit, vegetable, and micronutrient consumption but also lead to excess energy consumption. J. Nutr., 140: 612–617.

Leroy, J.L., Razak, A.A. & Habicht, J.P. 2008. Only children of the head of household benefit from increased household food diversity in northern Ghana. J., Nutr., 138: 2258–2263.

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R. & Searchinger, T. 2013. Reducing Food Loss and Waste. Working Paper, Installment 2 of Creating a Sustainable Food Future. pp. 1–40. Washington, DC: World Resources Institute.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy ,N., Meybeck, A., Neufeldt Remington, T., Thi Sen, P., Sessa, R., Shula, R., Tibu, A. & Torquebiau, E. 2014. Climate-smart agriculture for food security. Nature Climate Change, 4: 1068-1072. doi:10:1038/nclimate2437.

Lobao L. 1990. *Locality and inequality: farm and industry structure and socioeconomic conditions.* New York: State University of New York Press.

Loos, J., Abson, D.J., Chappell, M.J., Hanspach, J., Mikulcak, F., Tichit, M. & Jischer, J. 2014. Putting meaning back into “sustainable intensification”. Front Ecol. Environ., doi:10.1890/130157.

Lourme-Ruiz, A., Dury, S. & Martin-Prevel, Y. 2016. Do you eat what you sow? linkages between farm production diversity, agricultural income and dietary diversity in burkina faso. *Cahiers Agricultures,* 25(6). doi:10.1051/cagri/2016038.

Lovell, S.T., DeSantis, S., Nathan, C.A., Olson, M.B., Mendez, V.E., Kominami, H.C., Erickson, D.L., Morris, K.S. & Morris, W.B. 2010. Integrating agroecology and landscape multifunctionality in Vermont: An evolving framework to evaluate the design of agroecosystems. Agricultural Systems 103: 327-341.

Luedeling, E., Smethurst, P.J., Baudron, F., Bayala, J., Huth, N.I., van Noordwijk, M., Ong, C.K., Mulia, R., Lusiana, B., Muthuri, C.L. & Sinclair, F. 2016. Field-scale modeling of tree–crop interactions: Challenges and development needs Agricultural Systems 142: 51–69. https://www.sciencedirect.com/science/article/pii/S0308521X15300457

Lyson, T. and R. Welsh. 2005. Agricultural industrialization, anticorporate farming laws and rural community welfare. *Social Forces* 80: 311-27.

Lyson, T. R. Torres & R. Welsh. 2001. Scale of agricultural production, civic engagement and community welfare. *Social Forces* 80: 311-27.

Lyson, T. R. Torres and R. Welsh. 2001. Scale of agricultural production, civic engagement and community welfare. *Social Forces* 80: 311-27

Mahajan, P.V., Caleb, O.J., Gil, M.I., Izumi, H., Colelli, G., Watkins, C.B., Zude, M. 2017. Quality and safety of fresh horticultural commodities: Recent advances and future perspectives. Food Packaging and Shelf Life 14: 2-11 Part: A Special Issue: SI

Malapit, H.J.L. & Quisumbing, A.R. 2015. What dimensions of women's empowerment in agriculture matter for nutrition in Ghana? Food Policy, 52: 54–63. http://dx.doi.org/10.1016/j.foodpol.2015.02.003.

Malapit, H.J.L., Kadiyala, S., Quisumbing, A.R., Cunningham, K. & Tyagi, P. 2015.Women's empowerment mitigates the negative effects of low production diversity on maternal and child nutrition in Nepal. J. Dev. Stud., 51:1097–1123. http://dx.doi.org/10.1080/00220388.2015.1018904.

Mander, 2012

Mannan, M., Al-Ansari, T., Mackey, H.R. & Al-Ghamdi, S.G. 2018. Quantifying the energy, water and food nexus: A review of the latest developments based on life-cycle assessment. Journal of Cleaner Production, Volume: 193: 300-314.

Mapfumo P., Adjei-Nsiah S., Mtambanengwe F., Chikowo R. and Giller K.E. 2013. Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa. *Environmental Development* 5:6–22.

Marks *et al.,* 2010

Marten, G.G. 1988. Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystem assessment*. Agricultural Systems,* 26: 291–316.

MaryAnne, 2015

Masset, E., Haddad, L., Cornelius, A., & Isaza-Castro, J. (2012). Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review. *BMJ*, *344*(jan17 1), d8222–d8222. https://doi.org/10.1136/bmj.d8222

Mattsson, K. 2015. Standards for Fresh Fruit and Vegetables - for Trading in High Quality Products. 6th International Conference on Managing Quality in Chains. Cranfield, England. Edited by:Terry, LA; Cools, K; Alamar, MC Acta Horticulturae 1091:73-79

McClintock, N. 2011. 'From Industrial Garden to Food Desert: Unearthing the Root Structure of Urban Agriculture in Oakland, California.' In Cultivating Food Justice: Race, Class, and Sustainability, ed. A. Alkon and J. Agyeman, 89–120. Cambridge, MA: MIT Press.

McCune, N.M., González, Y.R., Alcántara, E.A., Martínez, O.F., Fundora, C.O., Arzola, N.C., Cairo, P.C., D'Haesse, M., DeNeve, S. & Hernández, F.G. 2011. Global questions, local answers: soil management and sustainable intensification in diverse socioeconomic contexts of Cuba. J. Sustain. Agric., 35(6):650–670. doi:10.1080/10440046.2011.586595.

McGrath, D., Beiriger, R., Nuessly, G.S., Tepa-Yotto, T.G., Hodson, D., Kimathi, E., Elias, F., Obaje, J.A., Mulaa, M., Mendes, A.P., Mabrouk, A.F.A., Belayneh, Y. 2018. Monitoring, surveillance and scouting for Fall Armyworm, in: Fall ArmyWorm in Africa: A Guide for Integrated Pest Management. CDMX: CIMMYT, Mexico, pp. 11–27.

Méndez *et al.,* 2013

Méndez, V.E, Christopher, M.B. & Roseann Cohen, R. 2013. Agroecology as a transdisciplinary, participatory, and action-oriented approach. *Agroecology and Sustainable Food Systems* 37 (1): 3-18.

Méndez, V.E., Bacon C.M. & Cohen, R. 2015. Introduction: Agroecology as a transdisciplinary, participatory, and action-oriented approach. In Méndez, V.E. *et al.* eds., Agroecology: a transdisciplinary, participatory and action-oriented approach. pp. 1–22. Advances in Agroecology Series. CRC Press/Taylor & Francis.

Méndez, V.E., Bacon, C.M. & Cohen, R. 2013. Agroecology as a transdisciplinary, participatory, and action-oriented approach. *Agroecology and Sustainable Food Systems*, 37: 3–18.

Méndez, V.E., Bacon, C.M., Cohen, R. & Gliessman, S.R. 2015. *Agroecology: a transdisciplinary, participatory and action-oriented approach.* https://www.crcpress.com/Agroecology-A-Transdisciplinary-Participatory-and-Action-oriented-Approach/Mendez-Bacon-Cohen-Gliessman/p/book/9781482241761

Michelini, L., Principato, L., Iasevoli, G. 2018. Understanding Food Sharing Models to Tackle Sustainability Challenges. Ecological Economics 145:205-217

Michon, G. & de Foresta, H. 1997. Agroforests: Pre-Domestication of Forest Trees or True Domestication of Forest Ecosystems? Journal of Agricultural Science. 45: 451–462.

Midega, C.A.O., Pittchar, J.O., Pickett, J.A., Hailu, G.W., Khan, Z.R. 2018. A climate-adapted push-pull system effectively controls Fall Armyworm, Spodoptera frugiperda (J E Smith), in maize in East Africa. Crop Prot. 105, 10–15.

Mier y Terán Giménez Cacho, M., Giraldo, O. F., Aldasoro, M., Morales, H., Ferguson, B. G., Rosset, P., … Campos, C. 2018. Bringing agroecology to scale: key drivers and emblematic cases. *Agroecology and Sustainable Food Systems*, *42*(6), 637–665. https://doi.org/10.1080/21683565.2018.1443313

Mier y Terán Giménez Cacho, Mateo, Omar Felipe Giraldo, Miriam Aldasoro, Helda Morales, Bruce G. Ferguson, Peter Rosset, Ashlesha Khadse & Carmen Campos (2018) Bringing agroecology to scale: key drivers and emblematic cases, Agroecology and Sustainable Food Systems, 42:6, 637-665, DOI: 10.1080/21683565.2018.1443313 https://doi.org/10.1080/21683565.2018.1443313

Miles, A., DeLonge, M. S. & Carlisle, L. 2017. Triggering a positive research and policy feedback cycle to support a transition to agroecology and sustainable food systems. *Agroecology and Sustainable Food Systems*, *41*(7): 855-879. https://doi.org/10.1080/21683565.2017.1331179

Miller, L.C., Joshi, N., Lohani, M., Rogers, B., Loraditch, M., Houser, R., Singh, P. & Mahato, S. 2014. Community development and livestock promotion in rural Nepal: effects on child growth and health, Food Nutr., Bull., 35(3): 312–326.

Mirsky, S.B., Ryan, M.R., Curran, W.S., Teasdale, J.R., Maul, J., Spargo, J.T., Moyer, J., Grantham, A.M., Weber, D., Way, T.R., *et al.* 2012. Conservation tillage issues: Cover crop-based organic rotational no-till grain production in the mid-Atlantic region, USA. Renewable Agriculture and Food Systems, 27: 31–40.

Mollison, B. 1988. Permaculture: A Designer's Manual. Permaculture: A Designer's Manual.

Mondal, S., Rutkoski, J.E., Velu, G. *et al.* 201) Harnessing Diversity in Wheat to Enhance Grain Yield, Climate Resilience, Disease and Insect Pest Resistance and Nutrition Through Conventional and Modern Breeding Approaches. Frontiers in Plant Science, 7: 991, DOI: 10.3389/fpls.2016.00991.

Montpellier Panel. 2013. Sustainable Intensification: A New Paradigm for African Agriculture. Agriculture for Impact, Imperial College, London.

Morales, H., Ferguson, B., Marín, L., Gutiérrez, D., Bichier, P., & Philpott, S. (2018). Agroecological Pest Management in the City: Experiences from California and Chiapas. *Sustainability*, *10*(6), 2068. https://doi.org/10.3390/su10062068

Mortensen, D.A., Egan, J.F., Maxwell, B.D., Ryan, M.R. & Smith, R.G. 2012. Navigating a Critical Juncture for Sustainable Weed Management. *BioScience,* 62(1): 75–84. https://doi.org/10.1525/bio.2012.62.1.12

Mueller, N.D., Gerber, J.S., Johnston, M., Ray, D.K., Ramankutty, N. & Foley, J.A. 2012. Closing yield gaps through nutrient and water management. Nature, 490(7419): 254–257. doi:10.1038/nature11420.

Muller, A., Schader, C., El-Hage Scialabba, N., Brüggemann, J., Isensee, A., Erb, K.H., Smith, P., Klocke, P., Leiber, F., Stolze, M. & Niggli, U. 2017. *Strategies for feeding the world more sustainably with organic agriculture. Nature* Communications. DOI: 10.1038/s41467-017-01410-w https://www.nature.com/articles/s41467-017-01410-w.pdf

Maas, B., Clough, Y., Tscharntke, T., 2013. Bats and birds increase crop yield in tropical agroforestry landscapes. Ecol. Lett. 16, 1480–1487.

Maas, B., Karp, D.S., Bumrungsri, S., Darras, K., Gonthier, D., Huang, J.C.-C., Lindell, C.A., Maine, J.J., Mestre, L., Michel, N.L., Morrison, E.B., Perfecto, I., Philpott, S.M., Şekercioğlu, Ç.H., Silva, R.M., Taylor, P.J., Tscharntke, T., Van Bael, S.A., Whelan, C.J., Williams-Guillén, K., 2016. Bird and bat predation services in tropical forests and agroforestry landscapes: Ecosystem services provided by tropical birds and bats. Biol. Rev. 91, 1081–1101.

National Academies of Science (NAS). 2016. Genetically engineered crops : experiences and prospects / Committee on Genetically Engineered Crops: Past Experience and Future Prospects, Board on Agriculture and Natural Resources, Division on Earth and Life Studies. Washington, D.C. NAS.

Nelson, R. 1993. National Innovation Systems, Oxford University Press, Oxford.

NELSON, R., COE, R., & HAUSSMANN, B. 2016. Farmer research networks as a strategy for matching diverse options and contexts in smallholder agriculture. Experimental Agriculture, 1-20. doi:10.1017/S0014479716000454

Nestle, M. (2001). Genetically engineered "Golden" rice unlikely to overcome vitamin A deficiency. *Journal of the American Dietetic Association, 101*(3), 289-290. doi:10.1016/S0002-8223(01)00073-6

Ng, M., Fleming, T., Robinson, M., *et al.* 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the global burden of disease study 2013. *Lancet,* 384(9945): 766–781.

Ng'endo, M., Bhagwat, S. & Keding, G.B. 2016. Influence of Seasonal On-Farm Diversity on Dietary Diversity: A Case Study of Smallholder Farming Households in Western Kenya, *Ecology of Food and Nutrition*, 55:5: 403–427, DOI: 10.1080/03670244.2016.1200037.

Nicholls, C., Altieri, M.A. & Vazquez, L. 2016. Agroecology: principles for the conversion and redesign of farming systems. *Journal of Ecosystem & Ecography,* S5: 010. Doi:10.4172/2157-7625.S5-010

Novak, W.K. & Haslberger, A.G. 2000. Substantial equivalence of antinutrients and inherent plant toxins in genetically modified novel foods. *Food Chem Toxicol.,* 38: 473–483.

Nyantakyi-Frimpong, H. 2017. Agricultural diversification and dietary diversity: A feminist political ecology of the everyday experiences of landless and smallholder households in northern Ghana. *Geoforum*, 86: 63–75. https://doi.org/10.1016/j.geoforum.2017.09.003.

Nyantakyi-Frimpong, H., C. Hickey, E. Lupafya, L. Dakishoni, R. Bezner Kerr, B. Nyirenda, Z. Nkhonya, M. Katundu and G. Gondwe. 2017. A farmer-to-farmer agroecological approach to addressing food security in Malawi. In: *Everyday Experts: How people's knowledge can transform the food system*. Eds. Tom Wakeford, Javier Sanchez-Rodriguez, Marina Chang Christabel Buchanan and Colin Anderson. Center for Agroecology, Water and Resilience, Coventry University. P. 119-134.

Nyantakyi-Frimpong, H., F. N Mambulu, R. Bezner Kerr, I. Luginaah and E. Lupafya. 2016b. Agroecology and sustainable food systems: Participatory research to improve food security among HIV-affected households in northern Malawi. *Social Science and Medicine* 164: 89-99. doi 10.1016/j.socscimed.2016.07.020

Nyantakyi-Frimpong, H., J. Kangmennaang, R. Bezner Kerr, I. Luginaah, L. Dakishoni, E. Lupafya, L. Shumba, M. Katundu. 2016a. Agroecology and healthy food systems in semi-humid tropical Africa: Participatory research with vulnerable farming households in Malawi. *Acta Tropica* 175: 42-49 doi 10.1016/j.actatropica.2016.10.02

Nyéléni. 2007. *Forum for Food Sovereignty.* Sélingué, Mali. *23*-27 February 2007. https://nyeleni.org/DOWNLOADS/Nyelni_EN.pdf

Nyéléni. 2015. *International Forum for Agroecology.* Nyéléni Center, Sélingué, Mali. 24-27 February 2015. http://www.foodsovereignty.org/wp-content/uploads/2015/10/NYELENI-2015-ENGLISH-FINAL-WEB.pdf
Odum, E.P. 1969. The strategy of ecosystem development. *Science,* 164: 262–270.
OECD & Eurostat. 2005. *Oslo manual: guidelines for collecting and interpreting innovation data, third edition.* Oslo, Organisation for Economic Co-operation and Development (OECD). 166p. http://www.oecd-ilibrary.org/docserver/download/9205111e.pdf?expires=1499444095&id=id&accname=guest&checksum=02D385FCADEB0FFE34B9FEE2D97E1FE9
OECD, 1993
OECD. 2001. Innovative Networks: Co-operation in National Innovation Systems, OECD, Paris.
Oliver, B. 2016. The Earth Gives Us So Much': Agroecology and Rural Women's Leadership in Uruguay. Culture, Agriculture, Food and Environment 38 (1): 38–47. doi: 10.1111/cuag.12064.
Ong, C.K. & Huxley, P. (eds) 1996. Tree-Crop Interactions: A Physiological Approach. CAB International, 416 pp.
Owoputi, Ibukun, Nola Booth, Isaac Luginaah, Hanson Nyantakyi-Frimpong, Lizzie Shumba, Esther Lupafya, Laifolo Dakishoni and Rachel Bezner Kerr. 2018. Farmer to Farmer agroecological training and crop diversity improve children's intake of vitamin A rich foods and household food security in Malawi. Poster presentation at the *Agriculture, Nutrition and Health Academy Week*, Accra, Ghana, June 2018.
Oyarzun, P.J., Borja, R.M., Sherwood, S., Parra, V., 2013. Making sense of agrobiodiversity, diet, and intensification of smallholder family farming in the Highland Andes of Ecuador. Ecol Food Nutr 52, 515–541. doi:10.1080/03670244.2013.769099
Pagella, T.F. & Sinclair, F.L. 2014. Development and use of a new typology of mapping tools to assess their fitness for supporting management of ecosystem service provision. Landscape Ecology 29(3):383–99
Pandey, V.L., Mahendra Dev, S. Jayachandran, U. 2016. Impact of agricultural interventions on the nutritional status in South Asia: a review. Food Policy, 62: 28–40. http://dx.doi.org/10.1016/j.foodpol.2016.05.002.
Patel, P. & Pavitt, K. 1994 National innovation systems: why they are important and how they might be measured and compared. Econ. Innov. New Technol. 3(1):77-95.
Patel. R.C. 2012. Food Sovereignty: Power, Gender, and the Right to Food. PLoS Medicine 9 (6): e1001223. doi:10.1371/journal.pmed.1001223.
Pellegrini, L., Tasciotti, L., 2014. Crop diversification, dietary diversity and agricultural income: empirical evidence from eight developing countries. Canadian Journal of Development Studies / Revue canadienne d'études du développement 35, 211–227. doi:10.108 0/02255189.2014.898580
Pellegrino, E., Bedini, S., Nuti, M. & Ercoli, L. 2018. Impact of genetically engineered maize on agronomic, environmental and toxicological traits: a meta-analysis of 21 years of field data. *Scientific Reports*, 8, Article No 3113.
Pengue, W., Gemmill-Herren, B., Balázs, B., Ortega, E., Viglizzo, E., Acevedo, F., Diaz, D.N., Díaz de Astarloa, D., Fernandez, R., Garibaldi, L.A., Giampetro, M., Goldberg, A., Khosla, A. & Westhoek, H. 2018. Eco-agri-foodsystems: today's realities and tomorrow's challenges. In *TEEB for Agriculture & Food: Scientific and Economic Foundations*. Geneva: UN Environment.
Pérez-Marin, A. M., Rogé, P., Altieri, M. A., Forer, L. F. U., Silveira, L., Oliveira, V. M., & Domingues-Leiva, B. E. (2017). Agroecological and Social Transformations for Coexistence with Semi-Aridity in Brazil. Sustainability, 9(6), 990. https://doi.org/10.3390/su9060990
Petkovic, K. 2017 The food loss bank - A concept that could transform the food supply chain. Food Australia 69: 42–44.
Pimbert, M. & Moeller, N. 2018. Absent Agroecology Aid: On UK Agricultural Development Assistance Since 2010. Sustainability, 10(2), [505]. DOI: 10.3390/su10020505 http://www.mdpi.com/2071-1050/10/2/505/pdf
Pimbert, M. and S. Lemke. 2018. Food Environments: Using agroecology to enhance dietary diversity. In: *UNSCN (United Nations System Standing Committee on Nutrition) Report 43: Addressing Equity, Equality and Non-Discrimination in the Food System: Pathways to Reform*, p. 33-42. https://www.unscn.org/uploads/web/news/UNSCN-News43.pdf
Pimbert, M., & Moeller, N. (2018). Absent Agroecology Aid: On UK Agricultural Development Assistance Since 2010. *Sustainability*, *10*(2), 505. https://doi.org/10.3390/su10020505
Pimbert, M.P. 2015. Agroecology as an alternative vision to conventional development and climate-smart agriculture. *Development,* 58(2–3): 286–298. http://rdcu.be/pAqF
Pimbert, M.P. 2018. Democratizing knowledge and ways of knowing for food sovereignty, agroecology and biocultural diversity. In: Pimbert, M. P. (Ed.). Food sovereignty, agroecology and biocultural diversity: constructing and contesting knowledge. pp. 259–322. London; New York: Routledge, Taylor & Francis Group.
Pingali, P. 2015. Agricultural policy and nutrition outcomes – getting beyond the preoccupation with staple grains. *Food Security,* 7(3): 583–591.
Ponisio, L.C., M'Gonigle, L.K., Mace, K.C., Palomino, J., de Valpine, P., & Kremen, C. 2015. Diversification practices reduce organic to conventional yield gap. Proceedings of the Royal Society B: Biological Sciences, 282 (1799), 20141396. http://doi.org/10.1098/rspb.2014.1396.
Powell, B., Thilsted, S. H., Ickowitz, A., Termote, C., Sunderland, T. & Herforth, A. 2015. Improving diets with wild and cultivated biodiversity from across the landscape. *Food Security*, *7*(3): 535–554. https://doi.org/10.1007/s12571-015-0466-5.
Pratley, P. 2016. Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: A systematic review of evidence from the developing world. Soc., Sci., Med., 169: 119–131.

Pretty, J. & Bharucha, Z.P. 2014. Sustainable intensification in agricultural systems. *Annals of Botany*, 114: 1571–1596.
Pretty, J.N. 1997. The sustainable intensification of agriculture. Nat., Res., Forum., 21(4): 247–256.
Pretty, J.N. 2008. Agricultural sustainability: concepts, principles and evidence. Philos., Trans., R., Soc., 363(1491): 447–465. doi:10.1098/rstb. 2007.2163.
Pretty, J.N., Noble, A.D., Bossio, D., Dixon, J., Hine, R.E., Penning de Vries, F.W.T., Morison, J.I.L., 2006. Resource-conserving agriculture increases yields in developing countries. Environ. Sci. Technol. 40, 1114–1119. doi:10.1021/es051670d
Prieto, I., Violle, C., Barre, P., Durand, J.-L., Ghesquiere, M., Litrico, I., 2015. Complementary effects of species and genetic diversity on productivity and stability of sown grasslands. Nature Plants 1, 15033. doi:10.1038/nplants.2015.3
Qiao, F.B., Huang, J.K., Wang, S.K. & Qiang, L.I. 2017. The impact of Bt cotton adoption on the stability of pesticide use. *Journal of Integrative Agriculture*, 16(10): 2346–2356.
Randolph, T.F., Schelling, E., Grace, D., Nicholson, C.F., Leroy, J.L., Peden, D., Cole, D.C., Demment, M.W., Omore, A., Zinsstag, J. & Ruel, M. 2007. Invited review: role of livestock in human nutrition and health for poverty reduction in developing countries. J., Anim., Sci., 85: 2788–2800.
Rasmussen *et al.,* 2018
Rasmussen, L. V., Coolsaet, B., Martin, A., Mertz, O., Pascual, U., Corbera, E., … Ryan, C. M. (2018). Social-ecological outcomes of agricultural intensification. *Nature Sustainability*, *1*(6), 275–282. https://doi.org/10.1038/s41893-018-0070-8
Rasmussen, L.V., Coolsaet, B., Martin, A., Mertz, O., Pascual, U., Corbera,E., Dawson, N., Fisher, J.A., Franks, P. & Ryan, C.M. 2018. Social-ecological outcomes of agricultural intensification. Nature Sustainability, Vol 1 June 2018: 275–282.
Rawlins, R., Pimkina, S., Barrett, C.B., Pedersen, S. & Wydick, B. 2014. Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes. Food Policy, 44: 202–213. http://dx.doi.org/10.1016/j.foodpol.2013.12.003.
Reardon, T., Chan, K., Minten, B. & Adriano, L. 2012. The quiet revolution in staple food value chains: Enter the dragon, the elephant and the tiger. Manila, Asian Development Bank, and Washington, DC, International Institute for Food Policy Research.
Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, *2*(2), 15221. https://doi.org/10.1038/nplants.2015.221
Rico, E., Fenn, B., Abramsky, T. & Watts, C. 2011. Associations between maternal experiences of intimate partner violence and child nutrition and mortality: Findings from Demographic and Health Surveys in Egypt, Honduras, Kenya, Malawi and Rwanda. *Journal of Epidemiology and Community Health,* 65(4): 360–367.
Rivers, A., Barbercheck, M., Govaerts, B., Verhulst, N., 2016. Conservation agriculture affects arthropod community composition in a rainfed maize–wheat system in central Mexico. Appl. Soil Ecol. 100, 81–90.
Robbins, P (2004). Political ecology: a critical introduction. Blackwell Publishing
Rocha, C. 2009. "Developments in National Policies for Food and Nutrition Security in Brazil." Development Policy Review 27(1): 51–66.
Rockström *et al.* 2009
Rosenberg, N. 1994. *Exploring the Black Box: Technology, Economics, and History*, Cambridge University Press, Cambridge.
Rosset, P. M., Machín Sosa, B., Roque, A.M. & Ávila, D.R. 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: Social process methodology in the construction of sustainable peasant agriculture and food sovereignty. Journal of Peasant Studies 38 (1):161–91. doi:10.1080/03066150.2010.538584.
Rosset, P.M., Machn Sosa, B., Roque Jaime, A.M. & vila Lozano, D.R. 2011. The Campesino-to-Campesino Agroecology Movement of ANAP in Cuba: Social Process Methodology in the Construction of Sustainable Peasant Agriculture and Food Sovereignty. The Journal of Peasant Studies, 38(1): 161–191. doi:10.1080/03066150.2010.538584.
Royal Society London. 2009. Reaping the benefits: science and the sustainable intensification of global agriculture. The Royal Society, London, UK, 72 p.
Ruben, R. & Lee, D.R. 2000. Combining internal and external inputs for sustainable intensification No. 65. International Food Policy Research Institute (IFPRI).
Ruel, M.T. & Alderman, H. 2013. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet, 382, 536–551. http://dx.doi.org/10.1016/S0140-6736(13)60843-0.
Ruel, M.T. 2001. Can Food-Based Strategies Help Reduce Vitamin A and Iron Deficiencies? A Review of Recent Evidence. Food Policy Review #5. International Food Policy Research Institute (IFPRI), Washington, DC.
Ruel, M.T., Alderman, H., 2013. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet 382, 536–551. http://dx.doi.org/10.1016/S0140-6736(13)60843-0.
Sagar, N.A., Pareek, S., Sharma, S., Yahia, E.M., Lobo, M.G. 2018. Fruit and Vegetable Waste: Bioactive Compounds, Their Extraction, and Possible Utilization. Comprehensive Reviews In Food Science and Food Safety 17(3): 512-531
Saravanan, R. & Suchiradipta, B. 2017. Agricultural Innovation Systems: Fostering Convergence for Extension. MANAGE Bulletin 2, National Institute of Agricultural Extension Management, Hyderabad, India.

Satterthwaite, D., McGranahan, G. & Tacoli, C. 2010. Urbanization and Its Implications for Food and Farming. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 365, 2809–2820. doi.org/10.1098/rstb.2010.0136.
Satzinger, F, R. Bezner Kerr and L. Shumba. 2009. Farmers integrate nutrition, social issues and agriculture through knowledge exchange in northern Malawi. *Ecology of Food and Nutrition* 48 (5): 369-382.
Schanes, K., Dobernig, K., Gözet, B. 2018. Food waste matters - A systematic review of household food waste practices and their policy implications. Journal of Cleaner Production 182: 978-991
Schipanski *et al.,* 2016
Schut, M., Kamanda, J., Gramzow, A., Dubois, T., Stoian, D., Andersson, J., . . . Lundy, M. 2018. Innovation platforms in agricultural research for development: Ex-ante Appraisal of the Purposes and Conditions Under Which Innovation Platforms can Contribute to Agricultural Development Outcomes. Experimental Agriculture, 1-22. doi:10.1017/S0014479718000200
Schutter, O. de, 2013. Gender equality and food security: women's empowerment as a tool against hunger. Asian Development Bank, Mandaluyong City, Metro Manila, Philippines.
Scialabba, N.El-H. 2007. Organic Agriculture and Food Security. Agriculture.
Scoones, 2002
Sefer and Ercan, 2011
Seline *et al.,* 2015
Semba, R., De Pee, S., Sun, K., Sari, M., Akhter, N. & Bloem, M. 2008. Eff ect of parental formal education on risk of child stunting in Indonesia and Bangladesh. Lancet, 371: 322–328.
Sen, A. (1981). *Poverty and famines: an essay on entitlement and deprivation*. New York: Oxford University Press. ISBN 9780198284635.
Séralini, G., Mesnage, R., Clair, E., Gress, S., de Vendômois, J. & Cellier, D. 2011. Genetically modified crops safety assessments: present limits and possible improvements. *Environ. Sci. Eur.,* 23(1): 10.
Seufert, V., Ramankutty, N. & Mayerhoffer, T. 2017. What is thing called organic? – How organic farming is codified in regulations. Food Policy, 68, 10–20.
Shaner, D.L. 2014. Lessons Learned From the History of Herbicide Resistance. *Weed Science*, 62(02): 427–431. https://doi.org/10.1614/WS-D-13-00109.1.
Shively, G., Sununtnasik, C., 2015. Agricultural diversity and child stunting in Nepal. Journal of Development Studies 51.
Silici, L. 2014. *Agroecology - what it is and what it has to offer***.** London, UK, IIED. 28 p. http://pubs.iied.org/pdfs/14629IIED.pdf
Sills, DL (1974). The environment movement and its critics. *Human Ecology* 3(1): 1-41.
Sinclair, F.L. & Walker D.H. 1998. Qualitative knowledge about complex agroecosystems. Part 1: a natural language approach to representation. Agricultural Systems 56: 341-363
Sinclair, F.L. 2004. Agroforestry. In: Encyclopedia of Forest Sciences (eds Burley J, Evans J and Youngquist JA). Elsevier, Amsterdam, pp 27-32
Sinclair, F.L. 2017. Systems science at the scale of impact: reconciling bottom-up participation with the production of widely applicable research outputs. In Sustainable Intensification in Smallholder Agriculture: An Integrated Systems Research Approach. (Eds I. Oborn, B. Vanlauwe, M. Phillips, R. Thomas, W. Brooijmans and K. Atta-Krah). London: Earthscan pp. 43-57.
Singh, B.K., Trivedi, P., Singh, S., Macdonald, C.A., & Verma, J.P. 2018. Emerging microbiome technologies for sustainable increase in farm productivity and environmental security. *Microbiology Australia*, 39(1): 17–23.
Sisay, B., Simiyu, J., Malusi, P., Likhayo, P., Mendesil, E., Elibariki, N., Wakgari, M., Ayalew, G., Tefera, T., 2018. First report of the fall armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae), natural enemies from Africa. J. Appl. Entomol. 142, 800–804.
Smale *et al.,* 2009
Smith Dumont, E. Gnahou, GM, Ohouo, L, Sinclair, FL & Vaast P. 2014. Farmers in Côte d'Ivoire value integrating tree diversity in cocoa for the provision of ecosystem services. Agroforestry Systems 88(6): 1047-1066
Smith Dumont, E., C. Ky-Dembele, J. Bayala, R. Coe, S. Nadembèga, S. Barry, T. Pagella and F. Sinclair (in press). Seeing the wood and the trees: conflicts in local knowledge reveal context dependent impacts of tree diversity on soil fertility and livelihood resilience. Ecology and Society (in press)
Smith Dumont, E., Gassner, A., Agaba, G., Nansamba, R & Sinclair, F. 2018. The utility of farmer ranking of tree attributes for selecting companion trees in coffee production systems. Agroforestry Systems (online) https://doi.org/10.1007/s10457-018-0257-z
Smith, L. C., & Haddad, L. 2015. Reducing Child Undernutrition: Past Drivers and Priorities for the Post-MDG Era. *World Development*, *68*, 180–204. https://doi.org/10.1016/j.worlddev.2014.11.014
Smith-Dumont, E., Bonhomme, S., Pagella, T., F. & Sinclair, F.L. 2017. Structured Stakeholder Engagement Leads To Development of More Diverse and Inclusive Agroforestry Options. *Experimental Agriculture*: 1–23. https://doi.org/10.1017/S0014479716000788
Snapp, S.S. & Pound, B. (eds). 2017. *Agricultural Systems: Agroecology and Rural Developmen*t. 2nd edition. Elsevier, Boston MA.
Snapp, S.S., Blackie, M.J., Gilbert, R.A., Bezner Kerr, R. & Kanyama-Phiri, G.Y. 2010. Biodiversity can support a greener revolution in Africa. 2010. *Proceedings of the National Academy of Sciences*, 107(48): 20840–20845 doi:10.1073/pnas.1007199107

Sousa, E.H.S., Matos, M.C.B., Almeida, R.S., Teodoro, A.V. 2011. Forest fragments' contribution to the natural biological control of Spodoptera frugiperda Smith (Lepidoptera: Noctuidae) in Maize. Braz. Arch. Biol. Technol. 54, 755–760.

Spedding, CRW (1996). *Agriculture and the citizen*. Chapman and Hall, London 282 pp.

Sraboni, E., Malapit, H.J., Quisumbing, A.R. & Ahmed, A.U. 2014. Women's empowerment in agriculture: what role for food security in Bangladesh? World Dev., 61: 11–52. http://dx.doi.org/10.1016/j.worlddev.2014.03.025

Stassart, P.M., Baret, P.V., Grégoire, J.C., Hance, T., Mormont, M., Reheul, D., Stilmant, D., Vanloqueren, G., Vissser, M. 2012. L'agroécologie: trajectoire et potentiel. Pour une transition vers des systèmes alimentaires durables. *In* D. Van Dam, M. Streith, J. Nizet & P.M. Stassart, eds. *Agroéocologie, entre pratiques et sciences sociales*, pp. 27–51. Dijon, France, Educagri.

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S. 2015. Planetary Boundaries: Guiding human development on a changing planet. Science Vol. 347 no. 6223 DOI:10.1126/science.1259855 https://www.ncbi.nlm.nih.gov/pubmed/25592418 doi:10.1126/science.1259855

Stilgoe, J., Owen, R. & Macnaghten, P. 2013. Developing a framework for responsible innovation. *Research Policy,* 42(9): 1568–1580. http://dx.doi.org/10.1016/j.respol.2013.05.008

Stone, 2007

Stone, G. D., & Glover, D. (2011). Genetically modified crops and the 'food crisis': discourse and material impacts. *Development in Practice*, *21*(4–5), 509–516. https://doi.org/10.1080/09614524.2011.562876

Struik, P.C. & Kuyper, T. 2017. Sustainable intensification in agriculture: the richer shade of green. A review. *Agronomy for Sustainable Development*, 37(5): Article 39

Sun Star. 2011b. The NorMinVeggies experience: Finding strength in consolidation. http://www.sunstar.com.ph/cagayan-de-oro/business/2011/11/16/norminveggies-experience-finding-strength-consolidation-190960

Swisher, M.E., Ruiz-Menjivar, J. & Koenig, R. 2017. Value chains in renewable and sustainable food systems. Renewable Agriculture and Food Systems, 33(1): 1–5.

Tabashnik, B.E., Brévault, T. & Carrière, Y. 2013. Insect resistance to Bt crops: lessons from the first billion acres. *Nat. Biotechnol.,* 31: 510–521. https://doi.org/10.1038/nbt.2597.

Talukder, A., Kiess, L., Huq, N., Pee, S. de, Darnton-Hill, I., Bloem, M.W., 2000. Increasing the production and consumption of Vitamin A —rich fruits and vegetables: lessons learned in taking the Bangladesh homestead gardening programme to a national scale. Food Nutr Bull 21, 165–172. doi:10.1177/156482650002100210

Tansley, A.G. 1935. "The use and abuse of vegetational terms and concepts". *Ecology*. **16** (3): 284–307. doi:10.2307/1930070. JSTOR 1930070.

TEEB (The Economics of Ecosystems and Biodiversity). 2018. Measuring what matters in agriculture and food systems: a synthesis of the results and recommendations of TEEB for Agriculture and Food's Scientific and Economic Foundations report. Geneva: UN Environment.

TEEB. 2018. TEEB for Agriculture & Food: Scientific and Economic Foundations. Geneva: UN Environment.

Thapa, B., Walker, D.H. & Sinclair, F.L. 1997. Indigenous knowledge of the feeding value of tree fodder. Animal Feed Science and Technology 67: 97-114.

The Hindu Business Line. 2012. More Bengal farmers turn to Atlanta potatoes. http://www.thehindubusinessline.com/industry-and-economy/agribiz/more-bengal-farmers-turn-to-atlanta-potatoes/article4203936.ece

Thierfelder, C., Niassy, S., Midega, C., Sevgan, S., van den Burg, J., Prasanna, B.M., Baudron, F., Harrison, R.D., 2018. Low-cost agronomic practices and landscape management approaches to control FAW, in: Fall Armyworm in Africa: A Guide for Integraded Pest Management. CDMX: CIMMYT, Mexico, pp. 89–96.

Thompson, J & Scoones, I (2009). Addressing the dynamics of agri-food systems: an emerging agenda for social science research. *Environmental Science and Policy* 12(4): 386-397.

Thorne, P.J., Subba, D.B., Walker, D.H., Thapa, B., Wood, C.D. & Sinclair, F.L. 1999. The basis of indigenous knowledge of tree fodder quality and its implications for improving the use of tree fodder in developing countries. Animal Feed Science and Technology 81: 119 - 131

Tilman, D., Balzer, C., Hill, J. & Befort, B.L. 2011. Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences, 108(50), 20260-20264.

Timmermann, C., & Félix, G. F. (2015). Agroecology as a vehicle for contributive justice. *Agriculture and Human Values*, *32*(3), 523–538. https://doi.org/10.1007/s10460-014-9581-8

Tischler, W. 1965. *Agrarökologie.* Jena, Germany, Gustav Fischer Verlag. 499 p.

Tittonell, P. 2014. Ecological intensification of agriculture — sustainable by nature. *Current Opinion in Environmental Sustainability*, 8: 53–61.

Toledo and Barrera-Bassols, 2017

Traore, M., Thompson, B. & Thomas, G. 2012.*Sustainable nutrition security. Restoring the bridge between agriculture and health.* Rome, FAO.

Tsourgiannis, L., Karasavvoglou, A. & Florou, G. 2011. Consumers' attitudes towards GM free products in a European region the case of the Prefecture of Drama-Kavala-Xanthi in Greece. *Appetite.* 57: 448–458.

Tuomisto, H.L., Hodge, I.D., Riordan, P. & Macdonald, D.W. 2012. Does organic farming reduce environmental impacts? – a meta-analysis of European research. Journal of Environmental Management, 112: 309–320.

UN, 1966. International Covenant on Economic, Social and Cultural Rights (ICESCR).

UN. 2015. Sustainable Development Goals. 17 goals to transform our world. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

UN. 2015. Transforming our world: the 2030 agenda for sustainable development. A/RES/70/1. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

UNCESCR (UN Committee on Economic, Social and Cultural Rights). 1999. General Comment No. 12, on the Right to Adequate Food. UN doc. E/C/12/1999/5.

UNCTAD. 2013. Commodities and development report: perennial problems, new challenges and evolving perspectives (No. UNCTAD/SUC/2011/9). United Nations Conference on Trade and Development, New York and Geneva; UNCTAD, 2002. Escaping the poverty trap, The least developed countries report. United Nations, New York.

UNGA. 2013.

UNICEF, World Health Organization (WHO) and World Bank Group. 2017. *Joint Child Malnutrition Estimates 2017.* New York, UNICEF. http://www.who.int/nutgrowthdb/estimates2016/en/

Valin, H., Sands, R.D., van der Mensbrugghe, D. *et al.* 2014.The future of food demand: understanding differences in global economic models. *Agric.Econ.*, 45: 51–67.

van Bruggen, A.H., Gamliel, A. & Finckh, M.R. 2016. Plant disease management in organic farming systems. Pest Manag., Sci., 72(1): 30–44.

van Eenennaam, A.L. 2013. GMOs in animal agriculture: time to consider both costs and benefits in regulatory evaluations. *Journal of Animal Science and Biotechnology*, 4: 37.

Van Etten, J., Beza, E., Calderer, L., Van Duijvendijk, K., Fadda, C., Fantahun, B., . . . Zimmerer, K. 2016. First experiences with a novel farmer citizen science approach: crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (TRICOT). Experimental Agriculture, 1-22. doi:10.1017/S0014479716000739

van Jaarsveld, P.J., Faber, M., Tanumihardjo, S.A., Nestel, P., Lombard, C.J. & Benade, A.J.S. 2005 beta-Carotene-rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. American Journal of Nutrition, 81(5): 1080–1087.

Van Noorwijk et al. 2018. SDG synergy between agriculture and forestry in the food, energy, water and income nexus: reinventing agroforestry? Current Opinion in Environmental Sustainability in press.

Vanbergen and IPI, 2013

Vandermeer, J. & Perfecto, I. 2013. Complex traditions: Intersecting theoretical frameworks in agroecological research. *Agroecology and Sustainable Food Systems*, 37(1): 76–89. https://doi.org/10.1080/10440046.2012.717904

Vanloqueren, G. & Baret, P. 2009. How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. *Research Policy,* 38: 971–983.

von Braun, J., Puetz, D. & Webb, P. 1989: Irrigation technology and commercialization of rice in the Gambia: Effects on income and nutrition. International Food Policy Research Institute.

von_Schomberg R. 2011. (ed) Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields. Publications Office of the European Union, Luxembourg, pp 7-16. doi: i 10.2777/58723 https://philpapers.org/archive/VONTRR.pdf

Walker, D.H. & Sinclair, F.L. 1998. Qualitative knowledge about complex agroecosystems. Part 2: formal representation. Agricultural Systems 56: 365-386

Webb, P. 1989: Intra household decision-making and resource control: The effects of rice commercialization in West Africa. International Food Policy Research Institute.

Wesana, J., De Steur, H., Dora, M.K., Mutenyo, E., Muyama, L. & Gellynck, X. 2018 Towards nutrition sensitive agriculture. Actor readiness to reduce food and nutrient losses or wastes along the dairy value chain in Uganda. Journal of Cleaner Production, 182: 46–56.

Wezel, A. & David, C. 2012. Agroecology and the food system. *In* E. Lichtfouse, ed. *Agroecology and strategies for climate change,* pp. 17–34. Sustainable Agriculture Reviews Vol. 8. Dordrecht, Netherlands, Springer.

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D. & David, C. 2009. Agroecology as a science, a movement and a practice: a review. *Agronomy for Sustainable Development*, 29: 503–515. doi: 10.1051/agro/2009004

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D. & David, C. 2009. Agroecology as a science, a movement and a practice. A review. *Agronomy for Sustainable Development*, 29(4): 503–515. https://doi.org/10.1051/agro/2009004

Wezel, A., Casagrande, M., Celette, F., Vian, J.F., Ferrer, A. & Peigné, J. 2014. Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development*, 34(1): 1–20.

Wezel, A., Fleury, Ph., David, C. & Mundler, P. 2015. The food system approach in agroecology supported by natural and social sciences: topics, concepts, applications. *In* N. Benkeblia, ed. Agroecology, ecosystems and sustainability, pp. 181–199. Boca Raton, USA, CRC Press.

Wezel, A., Soboksa, G., McClelland, S., Delespesse, F. & Boissau, A. 2015. The blurred boundaries of ecological, sustainable, and agroecological intensification. A review. Agronomy for Sustainable Development, 35 (4): 1283-1295. DOI 10.1007/s13593-015-0333-y

White, A., Gallegos, D., Hundloe, T. 2011. The impact of fresh produce specifications on the Australian food and nutrition system: a case study of the north Queensland banana industry. Public Health Nutrition 14(8): 1489-1495.

Wibbelmann, M., Schmutz, U., Wright, J., Udall, D., Rayns, F., Kneafsey, M., Trenchard, L., Bennett, J. & Lennartsson, M. 2013. *Mainstreaming agroecology: implications for global food and farming systems.* Centre for Agroecology and Food Security Discussion Paper. Coventry, UK, Centre for Agroecology and Food Security. ISBN: 978-1-84600-0454. http://www.coventry.ac.uk/Global/05%20Research%20section%20assets/Research/CAFS/Publication,%20Journal%20Articles/MainstreamingAgroecology_WEB.pdf

Wiebe, N., Desmarais, A. A., & Wittman, H. eds. 2011. Food sovereignty in Canada: creating just and sustainable food systems. Halifax: Fernwood Pub.

Willer, H. & Lernoud, J. eds. 2017. The World of Organic Agriculture. Statistics and Emerging Trends 2016. Research Institute of Organic Agriculture (FiBL), Frick and IFOAM – Organics International, Frick, Switzerland, 340 p.

Willer, H. & Lernoud, J. eds. 2017. The World of Organic Agriculture. Statistics and Emerging Trends 2016. Research Institute of Organic Agriculture (FiBL), Frick and IFOAM – Organics International, Frick, Switzerland, 340 p.

Williams, T.O., Mul, M., Cofie, O., Kinyangi, J., Zougmore, R., Wamukoya, G., Nyasimi, M., Mapfumo, P., Ifejika Speranza, C., Amwata, D., Frid-Nielsen, S., Rosenstock, T. & Campbell, B. 2015. Climate Smart Agriculture in the African Context. Background Paper. Session 1. Unlocking Africa's Agricultural Potentials for Transformation to Scale. Feeding Africa – An Action Plan for Africa Agricultural Transformation, 21–23 October, 2015, Abdou Diouf International Conference Center, Dakar, Senegal. African Development Bank, African Union, United Nations Economic Commission for Africa.

Wittman, H. 2011. Food Sovereignty: A New Rights Framework for Food and Nature? Environment and Society: Advances in Research, 2 (1): 87–105.

Wittman, H., Chappell, M.J., Abson, D., Bezner Kerr, R., Blesh, J., Hanspach, J., Perfecto, I. & Fischer, J. 2017. A social-ecological perspective on harmonizing food security and biodiversity conservation. Regional Environmental Change, 17(5): 1291–1301, doi 10.1007/s10113-016-1045-9.

Wittman, H., Desmarais, A.A. & Wiebe, N. eds. 2010. Food Sovereignty: Reconnecting Food, Culture and Community. Blackpoint: Ferndale.

World Bank. 2006. Enhancing agricultural innovation: how to go beyond the strengthening of research systems. 135Washington DC, USA: The International Bank for Reconstruction and Development/The World Bank.

World Bank. 2007. From Agriculture to Nutrition. Pathways, Synergies and Outcomes. The International Bank for Reconstruction and Development/The World Bank, Washington, DC.

World Bank. 2010. *Innovation policy: a guide for developing countries.* Washington, DC. https://openknowledge.worldbank.org/handle/10986/2460

World Bank. 2012. Agricultural Innovation Systems: An Investment Sourcebook. Washington, World Bank, 660 p.

Wyckhuys, K.A.G., Zhang, W., Prager, S.D., Kramer, D.B., Delaquis, E., Gonzalez, C.E. & van der Werf, W. 2018. Biological control of an invasive pest eases pressures on global commodity markets. Environ. Res. Lett. 13, 094005.

Xin *et al.,* 2015

Zhou, X., Helmers, M.J., Asbjornsen, H., Kolka, R., Tomer, M.D. & Cruse, R.M. 2014. Nutrient removal by prairie filter strips in agricultural landscapes. J Soil Water Conserv 69: 54–64

Zomer RJ, Neufeldt H, Xu J, Ahrends A, Bossio DA, Trabucco A, van Noordwijk M & Wang M. 2016. Global tree cover and biomass carbon on agricultural land: The contribution of agroforestry to global and national carbon budgets. Scientific Reports 6 No. 29987

Goergen, G., Kumar, P.L., Sankung, S.B., Togola, A., Tamò, M. 2016. First report of outbreaks of the Fall Armyworm Spodoptera frugiperda (JE Smith)(Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. PloS One 11, e0165632.

Bensin, B.M. 1928. *Agroecological characteristics description and classification of the local corn varieties chorotypes*. Prague. (Publisher unknown).

Bensin, B.M. 1930. Possibilities for international cooperation in agroecological investigations. *Int. Rev. Agr. Mo. Bull. Agr. Sci. Pract.,* 21: 277–284.

Schumpeter, J.A. 1939. Business cycles: a theoretical, historical and statistical analysis of the capitalist process, New York, McGraw-Hill.

van Huis, A. 1981. Integrated pest management in the small farmer's maize crop in Nicaragua (PhD Thesis). Wageningen.

Sen, A. 1982. *Poverty and Famines: An Essay on Entitlements and Deprivation*. Oxford, Clarendon Press.

Posey, D.A. 1985. Indigenous Management of Tropical Forest Ecosystems: The Case of the Kayapo Indians of the Brazilian Amazon. Agroforestry Systems, 3: 139–158. https://doi.org/10.1007/BF00122640.

Francis, C.A. 1986. *Multiple Cropping Systems.* New York: MacMillan.

Altieri, M.A. 1987. Agroecology: the scientific basis of alternative agriculture. Boulder, USA, Westview Press.

Raintree, J. 1987. D&D user's manual. An introduction to agroforestry diagnosis and design. ICRAF, Nairobi 110 pp.

Hruska, A., Gladstone, S.M., 1988. Effect of period and level of infestation of the Fall Armyworm, Spodoptera frugiperda, on irrigated maize yield. Fla. Entomol. 71, 249–254.

Altieri, M.A. 1989. Agroecology: A new research and development paradigm for world agriculture. *Agr. Ecosyst. Environ.,* 27: 37–46.

Reijntjes, C., Haverkort, B. & Waters-Bayer, A. 1992. Farming for the future: an introduction to low-external-input and sustainable agriculture. London, Macmillan Press.

Carney, J. 1993: Converting the wetlands, engendering the environment: The intersection of gender with agrarian change in the Gambia. Economic Geography, 69: 329–348.
Clark, S., 1993. Generalist predators in reduced tillage corn: Predation on armyworm, habitat preferences and a method for measuring absolute densities. Virginia Polytechnic Institute and State University.
Thiollay, J-M. 1995. The Role of Traditional Agroforests in the Conservation of Rain Forest Bird Diversity in Sumatra. Conservation Biology, 9(2): 335–353. https://doi.org/10.1046/j.1523-1739.1995.9020335.x.
Agrawal, A. 1995. Dismantling the Divide Between Indigenous and Scientific Knowledge. *Development and Change*, 26(3): 413–439. https://doi.org/10.1111/j.1467-7660.1995.tb00560.x
Altieri, M.A. 1995. Agroecology: the science of sustainable agriculture. Boulder, USA, Westview Press.
Altieri, M.A. 1995. *Agroecology: the science of sustainable agriculture.* Boulder, USA, Westview Press.
Pretty, J.N., Thompson, J. & Hinchcliffe, F. 1996. Sustainable agriculture: impacts on food production and food security. International Institute for Environment and Development. Gatekeeper Series No. 60.
van Huis, A. Meerman, F., 1997. Can we make IPM work for resource-poor farmers in sub-Saharan Africa? Int. J. Pest Manag. 43, 313–320.
Rosset, P.M. & Altieri, M.A. 1997. Agroecology versus input subsitution: a fundamental contradiction of sustainable agriculture. *Society & Natural Resources,* 10(3): 283–295. http://dx.doi.org/10.1080/08941929709381027
Matson, P.A., Parton, W.J., Power, A.G. & Swift, M.J. 1997. Agricultural intensification and ecosystem properties. Science, 277(5325): 504–509. doi:10.1126/science.277.5325.504.
Brake, J. & Vlachos, D. 1998. Evaluation of transgenic Event 176 "Bt" corn in broiler chicken. *Poult Sci.,* 77: 648–653.
Sinclair, F.L. & Walker, D.H. 1999. A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension. In: L.E. Buck, J.P. Lassoie and E.C.M. Fernandes (eds). Agroforestry in Sustainable Agricultural Systems. Lewis Publishers, New York pp. 245-275
Sinclair, F.L. 1999. A general classification of agroforestry practice. Agroforestry Systems 46(2): 161- 180.
Pretty, J. 1999. Can Sustainable Agriculture Feed Africa? New Evidence on Progress, Processes and Impacts. Environment, Development and Sustainability, 1(3-4): 253–274. https://doi.org/10.1023/a:1010039224868.
Altieri, M.A. 2000. Multifunctional dimensions of ecologically-based agriculture in Latin America. *International Journal of Sustainable Development & World Ecology*, 7: 62–75. doi.org/10.1080/13504500009470029
Swaminathan, M.S. 2000. An evergreen revolution. *Biologist,* 47(2): 85–89.
Abate, T., van Huis, A., Ampofo, J.K.O., 2000. Pest management strategies in traditional agriculture: An African perspective. Annu. Rev. Entomol. 45, 631–659.
Holt-Giménez, E., 2002. Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring. Agriculture, Ecosystems & Environment 93, 87–105. doi:10.1016/S0167-8809(02)00006-3
Altieri, M.A. 2002. Agroecology: the science of natural resource management for poor farmers in marginal environments. *Agriculture, Ecosystems and Environment,* 93(1–3): 1–24. https://doi.org/10.1016/S0167-8809(02)00085-3
Holmgren, D. 2002. Permaculture : Principles & Pathways beyond Sustainability. Publish. https://doi.org/10.9774/GLEAF.978-1-909493-73-5_185.
Pretty, J.N., Morison, J.I.L. & Hine, R.E. 2003. Reducing food poverty by increasing agricultural sustainability in developing countries. *Agriculture Ecosystems and Environment,* 95: 217–234. doi: 10.1016/S0167-8809(02)00087-7.
Rogers, E.M. 2003. Diffusion of Innovations, 5th edn. New York: The Free Press.
Deller, S. 2003. Agriculture and rural economic growth. *Journal of Agricultural and Applied Economics* 35: 517-27
Holmgren, D. 2003. Essence of Permaculture. Permaculture: Principles and Pathways To Sustainability.
von Hippel, E. 2004. Democratizing Innovation. Cambridge (Mass.): MIT Press.
Grindle, M. 2004. Good enough governance: poverty reduction and reform in developing countries. *Governance* 17 (4): 525-48.
Altieri, M.A. 2004. *Agroecology versus ecoagriculture: balancing food production and biodiversity conservation in the midst of social inequity*. Commission on Environmental, Economic and Social Policy Occasional Papers Issue 3. Gland. Switzerland, International Union for the Conservation of Nature.
Leeuwis, C & Van den Ban, A. 2004. Communication for Rural Innovation (Rethinking Agricultural Extension). Blackwell Science Ltd, Oxford, 412pp
Berti, P.R., Krasevec, J. & Fitzgerald, S. 2004. A review of the effectiveness of agriculture interventions in improving nutrition outcomes. Public Health Nutr. 7: 599–609. http://dx.doi.org/10.1079/PHN2003595.
Flemming, J.S. 2004. Ethical, cultural and spiritual objections to genetically modified organisms: a review of the New Zealand process and perspective. Altern Lab Anim. 2004 Jun;32 Suppl 1A:21-7. https://www.ncbi.nlm.nih.gov/pubmed/23577431
Bengtsston, J., Ahnstrom, J., Weibull, A. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology 42: 261-269
Lorber, J. 2005. Gender Inequality: Feminist Theories and Politics. Los Angeles, CA: Roxbury Publishing.
Windfuhr, M. & Jonsén, J. 2005. Food Sovereignty: Towards Democracy in Localized Food Systems. Bourton-on- Dunsmore, UK: FIAN-International; ITDG Publishing.
Holt-Gimenez, E. 2006. *Campesino a Campesino: voices from Latin America's Farmer to Farmer Movement for Sustainable Agriculture*. Oakland, USA, Food First Books.

FAO. 2006. Food Security. Policy Brief, June 2006, Issue 2. Food and Agriculture Organizaiton of the United Nations, Rome, Italy. http://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf

Guston, D. 2006. Responsible knowledge-based innovation. Society, 43(4), 19-21. doi:10.1007/bf02687530

Webber, M. 2007. Using value chain approaches in agribusiness and agriculture in sub-Saharan Africa: A methodological guide. Report prepared for the World Bank by J.E. Austin Associates, Inc. http://www.technoserve.org/files/downloads/vcguidenov12-2007.pdf

Oke, D.O. & Odebiyi, K.A. 2007. Traditional Cocoa-Based Agroforestry and Forest Species Conservation in Ondo State, Nigeria. Agriculture, Ecosystems and Environment, 122(3): 305–311. https://doi.org/10.1016/j.agee.2007.01.022.

Chen, J. 2007. Rapid Urbanization in China: A Real Challenge to Soil Protection and Food Security. *Catena*, 69 (1), 1-15. doi.org/10.1016/j.catena.2006.04.019.

Concepcion, S.D., Digal, L. & Uy, J. 2007. Innovative practice Philippines: The case of Normin Veggies in the Philippines. Regoverning Markets Innovative Practice series. London, International Institute for Environment and Development. http://pubs.iied.org/pdfs/G03259.pdf

Wyckhuys, K.A.G., O'Neil, R.J. 2007. Local agro-ecological knowledge and its relationship to farmers' pest management decision making in rural Honduras. Agric. Hum. Values 24, 307–321.

Sileshi. G., Akinnifesi, F.K., Ajayi, O.C. & Place, F. 2008. Meta-analysis of maize yield response to planted legume fallows and green manures in sub-Saharan Africa. Plant and Soil 307:1–19

Triplett, G.B. & Dick, W.A. 2008. No-Tillage Crop Production: A Revolution in Agriculture! Agronomy Journal 100, S-153.

Ericksen P.J. 2008. Conceptualizing food systems for global environmental change research. *Global Environmental Change,* 18(1): 234–245.

Veteto, J.R. & Lockyer, J. 2008. Environmental Anthropology Engaging Permaculture : Moving Theory and Practice Toward Sustainability. Agriculture, 30(1–2): 47–58. https://doi.org/10.1111/j.1556-486X.2008.00007.x.ven.

Leroy, J.L., Ruel, M. & Verhofstadt, E. 2009. The impact of conditional cash transfer programmes on child nutrition: a review of evidence using a programme theory framework. J. Dev. Effect, 1: 103–29.

Nweke, F. 2009. Controlling Cassava Mosaic Virus and Cassava Mealybug in Sub-Saharan Africa. IFPRI Discussion Paper 00912, IFPRI, Washington.

Assefa, A., Waters-Bayer, A., Fincham, R. & Mudahara, M. 2009. Comparison of frameworks for studying grassroots innovation: Agricultural Innovation Systems (AIS) and Agricultural Knowledge and Information Systems (AKIS), In: P. Sanginga, A. Waters-Bayer, S. Kaaria, J.Njuki, C. Wettasinha (Eds.), Innovation Africa: Enriching farmers livelihoods (pp. 35–56). Earthscan, London. http://www.cgiar-ilac.org/files/Assefa_Comparison.pdf

Duffy, M. 2009. Economies of size in production agriculture. *Journal of Hunger and Environmental Nutrition*, 4(3–4): 375–392.

Ishii-Eiteman, M. 2009. Food Sovereignty and the International Assessment of Agricultural Knowledge, Science and Technology for Development. Journal of Peasant Studies, 36(3): 689–700.

Adesina, A. 2009. *Taking advantage of science and partnerships to unlock growth in Africa's breadbaskets.* Speech by Dr Akinwumi Adesina, Vice President, Alliance for a Green Revolution in Africa (AGRA). Science Forum 2009, Wageningen, The Netherlands, 17 June.

Jordan, R., Muller, A., Oudes, A. 2009. Organic Agriculture: a Guide to Climate Change and Food Security. Bonn, Germany: International Federation of Organic Movements, European Union Group.

McMichael, P. 2009. A Food Regime Genealogy. Journal of Peasant Studies 36 (1): 139–169. https://devsoc.cals.cornell.edu/sites/devsoc.cals.cornell.edu/files/shared/documents/McMichael-Food-regime-genealogy-JPS-2009-pdf.pdf

Wezel, A. & Soldat, V. 2009. A quantitative and qualitative historical analysis of the discipline of agroecology. *International Journal of Agricultural Sustainability,* 7(1): 3–18.

Pretty, J. 2009. Can Ecological Agriculture Feed Nine Billion People? The Monthly Review, https://doi.org/10.14452/MR-061-06-2009-10_5.

Cuellar, A.D. & Webber, M.E. 2010. Wasted food, wasted energy: the embedded energy in food waste in the United States, Environ. Sci. Technol., 44: 6464–6469.

Bacon, C.M. 2010. A spot of coffee in crisis: Nicaraguan smallholder cooperatives, fair trade networks and gendered empowerment. Latin American Perspectives 17(37): 50-71.

Scialabba, N.E. & Müller-Lindenlauf, M. 2010. Organic Agriculture and Climate Change. *Renewable Agriculture and Food Systems*, 25 (2), 158-169. doi.org/10.1017/S1742170510000116.

van der Veen, M. 2010. Agricultural innovation: invention and adoption or change and adaptation? World Archaeology, 42(1): 1–12.

White, M.M. 2010. ''Shouldering Responsibility for the Delivery of Human Rights: A Case Study of the D-Town Farmers of Detroit.'' Race/Ethnicity: Multidisciplinary Global Perspectives 3(2): 189–211.

Gottlieb, R. & Joshi, A. 2010. Food Justice. Cambridge.

Koohafkan, P. & Altieri, M.A. 2010. *Globally important agricultural heritage systems: a legacy for the future*. Rome. http://www.fao.org/fileadmin/templates/giahs/PDF/GIAHS_Booklet_EN_WEB2011.pdf

Barber, S.L. & Gertler, P.J. 2010. Empowering women: how Mexico's conditional cash transfer programme raised prenatal care quality and birth weight. J. Dev. Effect., 2: 51–73.

Knopp, D. & Foster, J. 2010. The economics of sustainability. The Woods Family Trust and the Gatsby Trust. http://www.idhsustainabletrade.com/site/getfile.php?id=331.

Wyckhuys, K.A.G., O'Neil, R.J. 2010. Social and ecological facets of pest management in Honduran subsistence agriculture: Implications for IPM extension and natural resource management. Environ. Dev. Sustain. 12, 297–311.

Keating, B.A. & Carberry, P.S. 2010.Sustainable production, food security and supply chain implications. *Asp. Appl. Biol.,* 102: 7–20.

De Schutter, O. 2010. *Agro-ecology and the right to food.* Report presented to the Human Rights Council A/HRC/16/49, sixteenth session. New York, USA, United Nations. http://www.srfood.org/images/stories/pdf/officialreports/20110308_a-hrc-16-49_agroecology_en.pdf

Lairon D. 2010. Nutritiona l quality and safety of organic food. A review. Agronomy for Sustainable Development, 30: 33-41. DOI: 10.1051/agro/2009019

Ching, L.L., Edwards, S. & Scialabba, N.E 2011. *Climate Change and Food Systems Resilience in Sub-Saharan Africa*. Development. FAO, Rome, Italy.

Altieri, M.A. & Toledo, V.M. 2011. The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty and empowering peasants. *Journal of Peasant Studies*, 38: 587-612.

Kouser, S. & Qaim, M. 2011. Impact of Bt cotton on pesticide poisoning in smallholder agriculture: A panel data analysis. *Ecological Economics,* 70: 2015–2113.

Conrad, C.C. & Hilchey, K.G. 2011. A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment*, 176(1–4): 273–291. https://doi.org/10.1007/s10661-010-1582-5

Sun Star. 2011a. Northern Mindanao group cites as market facilitator for small farmers. http://www.sunstar.com.ph/cagayan-de-oro/business/northernmindanao- group-cited-market-facilitator-small-farmers

Alkon, A. H. & Agyeman, J. 2011. Cultivating Food Justice: Race, Class, and Sustainability, Cambridge: MIT Press.

Ajayi, O.C., Place, F., Akinnifesi, F.K. & Sileshi, G.W. 2011. Agricultural success from Africa: The case of fertilizer tree systems in southern Africa (Malawi, Tanzania, Mozambique, Zambia and Zimbabwe). International Journal of Agricultural Sustainability 9:129–136. https://www.tandfonline.com/doi/pdf/10.3763/ijas.2010.0554

Pretty, J.N., Toulmin, C. & Williams, S. 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability, 9(1):5 24. doi:10.3763/ijas. 2010.0583.

De Schutter, O. 2011. *Agroecology and the right to food*. Report of the Special Rapporteur on the right to food. United Nations. http://www.srfood.org/images/stories/pdf/officialreports/20110308_a-hrc-16-49_agroecology_en.pdf.

Koohafkan, P. & Cruz, M.J.D. 2011. Conservation and adaptive management of globally important agricultural heritage systems (GIAHS). *Journal of Resources and Ecology,* 2(1): 22–28.

Koohafkan, P., Altieri, M.A. & Holt Gimenez, E. 2012. Green Agriculture: Foundations for Biodiverse, Resilient and Productive Agricultural Systems. *International Journal of Agricultural Sustainability*, 10 (1), 61-75. doi.org/10.1080/14735903.2011.610206.

Barrios E, Sileshi GW, Shepherd K and Sinclair F. 2012. Agroforestry and soil health: Linking trees, soil biota and ecosystem services. In Wall DH, Bardgett RD,, Behan-Pelletier V, Herrick JE, Jones TH, Ritz K, Six J, Strong DR and van der Putten W, eds. Soil Ecology and Ecosystem Services. Oxford, UK: Oxford University Press. 315–330.

Alkon, A. H. & Mares, T. M. 2012. Food Sovereignty in US Food Movements: Radical Visions and Neoliberal Constraints, Agriculture and Human Values, 29(3): 347–359.

Friedrich, T., Kienzle, J. & Kassam, A. 2012. A new paradigm for sustainable intensification and its implications for agricultural mechanization. In: CIGR-EurAgEng (ed) Rural Development. International Conference of Agricultural Engineering, Valencia, p P-0416.

Heynen, N., Kurtz, H. E. & Trauger, A. 2012. Food Justice, Hunger and the City, Geography Compass, 6(5): 304–311. MA: MIT Press.

Hotz, C., Loechl, C., Lubowa, A. *et al.* 2012a. Introduction of beta-carotene-rich orange sweet potato in rural Uganda resulted in increased vitamin A intakes among children and women and improved vitamin A status among children. J. Nutr., 142 (10):1871–1880.

Kremen C. & Miles A. 2012. Ecosystem Services in Biologically Diversified versus Conventional Farming Systems: Benefits, Externalities, and Trade-Offs. *Ecology and Society*, 17(4): 40.

Minkoff-Zern, L-A. 2012 Knowing 'Good Food': Immigrant Knowledge and the Racial Politics of Farmworker Food Insecurity. Antipode. doi: 10.1111/j.1467-8330.2012.01016.x.

Seufert, V., Ramankutty, N. & Foley, J.A. 2012. Comparing the yields of organic and conventional agriculture. Nature, 485(7397): 229–232.

Alexandratos, N. & Bruinsma, J. 2012. *World agriculture towards 2030/2050: The 2012 revision*. ESA Working paper No.12-03.Rome, FAO.

Hawkes, C., Turner, R. & Waage, J. 2012. Current and Planned Research on Agriculture for Improved Nutrition: a Mapping and a Gap analysis. Technical Report. UK Department for International Development (DFID), London.

Leifeld, J. 2012. How sustainable is organic farming? Agriculture, Ecosystems and Environment, 150: 121– 122.

Mercer KL, Perales H, Wainwright, J. 2012. Climate change and the transgenic adaptation strategy: smallholder livelihoods, climate justice, and maize landraces in Mexico. Global Environ Change 22(2):495–504

Perez-Cassarino, J. 2012 A construção social de mecanismos alternativos de mercados no âmbito da Rede Ecovida de agroecologia, PhD diss., Universidade Federal do Paraná. http://acervodigital.ufpr.br/handle/1884/27480

Zeigler, J. 2012. Right to Food, Report of the Special Rapporteur on the right to food, A/HRC/7/5, para 17.

Burlingame, B. & Dernini, S. 2012. *Sustainable Diets*.. CABI, Wallingford, Oxfordshire/Boston, MA

De Schutter, O. 2012. Agroecology, a tool for the realization of the right to food. In: Lichtfouse E (ed) Agroecology and strategies for climate change. *Sustainable Agriculture Reviews,* 8. Springer, Dordrecht, The Netherlands, pp 1–16.

De Schutter, O. 2012. Reshaping Global Governance: The Case of the Right to Food: Global Governance and the Right to Food. Global Policy, 3(4): 480–483. https://doi.org/10.1111/j.1758-5899.2012.00203.x

Webb-Girard, A., Self, J.L., McAuliffe, C. & Olude, O. 2012. The effects of household foodproduction strategies on the health and nutrition outcomes of women and young children: a systematic review. Paediatr. Perinat. Epidermiol. 26: 205–222. http://dx.doi.org/10.1111/j.1365-3016.2012.01282.x.

van Engelen, A., Malope, P., Keyser, J. & Neven, D. 2012. Botswana agricultural value chain project: Beef value chain study. Rome, FA, and Gaborone, Ministry of Agriculture, Botswana.

Tittonell, P. & Giller, K.E. 2013. When yield gaps are poverty traps: the paradigm of ecological intensification in African smallholder agriculture. Field Crop Research, 143:76–90. doi: 10.1016/j.fcr.2012.10.007.

Shekar, M., Ruel-Bergeron, J., Herforth, A. & Module, A. 2013. Introduction. In: Improving nutrition through multisectoral approaches. Washington, DC, International Bank for Reconstruction and Development, International Development Association of The World Bank.

Bos, J.F., Smit, A.B.L. & Schröder, J.J. 2013. Is agricultural intensification in The Netherlands running up to its limits? NJAS Wageningen, Journal of Life Sciences, 66: 65–73.

Connor, D.J. 2013. Organically grown crops do not a cropping system make and nor can organic agriculture nearly feed the world. Field Crop Res. 144: 145–147.

Pardey, P. & Beddow, J. 2013. *Agricultural innovation: the United States in a changing global reality.* Chicago, USA, The Chicago Council on Global Affairs. https://www.thechicagocouncil.org/sites/default/files/Agricultural_Innovation_Final%281%29.pdf

Rhodes, C.J. 2013. Feeding and Healing the World: Through Regenerative Agriculture and Permaculture. *Science Progress*, 95 (4), 345-446. doi.org/10.3184/003685012X13504990668392.

Wheeler, T. & von Braun, J. 2013. Climate change impacts on global food security. Science, 341 (6145): 508–513.

Qaim, M. & Kouser, S. 2013. Genetically Modified Crops and Food Security. *PLoS ONE* 8(6): e64879.

Wiggins, S. & Keats, S. 2013. Leaping and learning: Linking smallholders to markets. London, Agriculture for Impact, Imperial College London. https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/LeapingandLearning_FINAL.pdf

Caron, P., Biénabe, E. & Hainzelin, E. 2014. Making transition towards ecological intensification of agriculture a reality: the gaps in and the role of scientific knowledge. *Current opinion in Environmental Sustainability,* 8: 44–52. http://dx.doi.org/10.1016/j.cosust.2014.08.004

Coe, R., Sinclair, F. & Barrios, E. 2014. Scaling up agroforestry requires research 'in' rather than 'for' development. Current Opinion in Environmental Sustainability. http://www.sciencedirect.com/science/article/pii/S1877343513001437

Webb, P. & Kennedy, E. 2014. Impacts of agriculture on nutrition: nature of the evidence and research gaps. Food Nutr. Bull., 35: 126–132.

Ploeg, J.D. van der & Ventura, F. 2014. Heterogeneity reconsidered. *Current Opinion in Environmental Sustainability*, 8: 23–28.

Andreasen, M. 2014. GM food in the public mind – facts are what they used to be. *Nature Biotechnology,* 32: 25.

Klümper, W. & Qaim, M. 2014. A meta-analysis of the impacts of genetically mofidifed crops. *Plos One*, 9(11): e111629.

Rogé, P., Friedman, A. R., Astier, M., & Altieri, M. A. 2014. Farmer Strategies for Dealing with Climatic Variability: A Case Study from the Mixteca Alta Region of Oaxaca, Mexico. *Agroecology and Sustainable Food Systems*, *38*(7), 786–811. https://doi.org/10.1080/21683565.2014.900842

Massicotte, M.J. 2014. Feminist political ecology and La Vía Campesina's struggle for food sovereignty through the experience of the Escola Latino-Americana de Agroecologia (ELAA). In Peter Andrée *et al.*, eds., *Globalization and Food Sovereignty: Global and Local Change in the New Politics of Food,* pp. 255-275, Toronto, University of Toronto Press.

Lasco, R.D., Delfino, R.J.P. & Espaldon, M.L.O. 2014. Agroforestry systems: helping smallholders adapt to climate risks while mitigating climate change. Wiley Interdiscip Rev Clim Change 5(6), 825–833

Barrows, G., Sexton, S. & Zilberman, D. 2014. Agricultural Biotechnology: The Promise and Prospects of Genetically Modified Crops. *Journal of Economic Perspectives,* 28(1): 99–120.

Wesseler, J. & Zilberman, D. 2014. The economic power of the Golden Rice opposition. *Environment and Development Economics,* February, 1–19.

Carlson, G.J., Kordas, K. & Murray-Kolb, L.E. 2015. Associations between women's autonomy and child nutritional status: a review of the literature. Matern Child Nutr., 11: 452–482.

Langen, N., Gobel, C., Waskow, F. 2015. The effectiveness of advice and actions in reducing food waste. Proceedings of the Institution of Civil Engineers – Waste and Resource Management 168(2): Article No. 1300036

Chiputwa, B., Spielman, D.J. & Qaim, M. 2015. Food standards, certification, and poverty among coffee farmers in Uganda. World Dev. 66: 400–412.

Altieri, M.A., Nicholls, C.I., Henao, A. & Lana, M.A. 2015. Agroecology and the Design of Climate Change-Resilient Farming Systems. *Agronomy for Sustainable Development*, 35 (3), 869–890. doi.org/10.1007/s13593-015-0285-2.

Carletto, G., Ruel, M., Winters, P., Zezza, A., 2015. Farm-level pathways to improved nutritional status: Introduction to the special issue. The Journal of Development Studies 51, 945–957. doi:10.1080/00220388.2015.1018908

Liebman, M., & Schulte L.A. 2015. Enhancing agroecosystem performance and resilience through increased diversification of landscapes and cropping systems. Elem Sci Anth. 2015; 3:41. DOI: http://doi.org/10.12952/journal.elementa.000041

Morris, J.R., Vandermeer, J., Perfecto, I., 2015. A keystone ant species provides robust biological control of the Coffee Berry Borer under varying pest densities. PLOS ONE 10, e0142850.

Olney, D.K., Pedehombga, A., Ruel, M.T., Dillon, A., 2015. A 2-year integrated agriculture and nutrition and health behavior change communication program targeted to women in Burkina Faso reduces anemia, wasting, and diarrhea in children 3–12.9 months of age at baseline: a cluster-randomized controlled trial. J. Nutr. 145, 1317–1324. doi:10.3945/jn.114.203539

Kanter, R., Walls, H.L., Tak, M., Roberts, F. & Waage, J. 2015. A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health. *Food Security*, 7: 767-777. doi:10.1007/s12571-015-0473-6

Kanter, R., Walls, H.L., Tak, M., Roberts, F., Waage, J., 2015. A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health. Food Sec. 7, 767–777. doi:10.1007/s12571-015-0473-6;

Offenberg, J., 2015. Ants as tools in sustainable agriculture. J. Appl. Ecol. 52, 1197–1205.

Kehlenbeck, K. & McMullin, S. 2015. Fruit tree portfolios for improved diets and nutrition. How to use the diversity of different fruit tree species available in Machakos county to provide better nutrition for smallholder farming families. Nairobi: World Agroforestry Centre. http://www.worldagroforestry.org/downloads/Publications/PDFS/BR15151.pdf

Fresco, L.O. 2015. *The new green revolution: bridging the gap between science and society. Current Science*. http://www.currentscience.ac.in/Volumes/109/03/0430.pdf

Schot, J. & Steinmuller E. 2016. Framing innovation policy for transformative change : innovation policy 3.0, Brighton: SPRU, Draft, 4/9/201

Bellon, M.R., Ntandou-Bouzitou, G.D. & Caracciolo, F. 2016. On-Farm Diversity and Market Participation Are Positively Associated with Dietary Diversity of Rural Mothers in Southern Benin, West Africa. *PLOS ONE*, 11(9): e0162535. https://doi.org/10.1371/journal.pone.0162535.

van Noordwijk, M., Coe, R., & Sinclair F. 2016. Central hypotheses for the third agroforestry paradigm within a common definition. Working paper 233, Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. DOI: http://dx.doi.org/10.5716/WP16079.PDF

Addison, L., & Schnurr, M. 2016. Growing burdens? Disease-resistant genetically modified bananas and the potential gendered implications for labor in Uganda. *Agriculture and Human Values*, *33*(4), 967–978. https://doi.org/10.1007/s10460-015-9655-2

Chappell, M.J. & Schneider, M. 2016. The new three-legged stool: agroecology, food sovereignty, and food justice. In: The Routledge Handbook of Food Ethics, eds. M. C. Rawlinson and C. Ward. New York: Routledge. p. 419–429.

Kouser, S., Abedullah & Qaim, M. 2016. Bt cotton and employment effects for female agriculturallaborers in Pakistan, *New Biotechnology*, 34: 40–46.

Meagher, R.L., Nuessly, G.S., Nagoshi, R.N., Hay-Roe, M.M. 2016. Parasitoids attacking Fall Armyworm (Lepidoptera: Noctuidae) in sweet corn habitats. Biol. Control 95, 66–72.

Mourad, M. 2016. Recycling, recovering and preventing “food waste”: competing solutions for food systems sustainability in the United States and France. Journal of Cleaner Production 126: 461–477).

Reganold, J.P., & Wachter, J.M. 2016. Organic agriculture in the twenty-first century. Nature Plants, 2(2), 15221. https://doi.org/10.1038/nplants.2015.221.

UNEP. 2016a. *Food Systems and Natural Resources.* A Report of the Working Group on Food Systems of the International Resource Panel. Westhoek, H, Ingram J., Van Berkum, S., Özay, L., and Hajer M.

FAO. COAG/2016/6. *Achieving Sustainable rural development through agricultural innovation.* COAG 25th Session. 26-30 September 2016. Rome. http://www.fao.org/3/a-mr236e.pdf

Ganges, S. 2016. From agency to capabilities; Sen and sociological theory. Current Sociology, Vol 64(1), https://doi.org/10.1177/0011392115602521

Murty, P.V.V.S., Rao, M.V. & Bamji, M.S. 2016. Impact of enriching the diet of women and children through health and nutrition education, introduction of homestead gardens and backyard poultry in rural India. Agric. Res. 5: 210–217. http://dx.doi.org/10.1007/s40003-016-0206-x.

Alaofè, H., Burney, J., Naylor, R. & Taren, D. 2016. Solar-powered drip irrigation impacts on crops production diversity and dietary diversity in Northern Benin. Food Nutr. Bull., 37: 164–175. http://dx.doi.org/10.1177/0379572116639710.

Hathaway, M.D. 2016. Agroecology and Permaculture: Addressing Key Ecological Problems by Rethinking and Redesigning Agricultural Systems. Journal of Environmental Studies and Sciences, 6(2): 239–250. https://doi.org/10.1007/s13412-015-0254-8.

Hathaway, M.D. 2016. Agroecology and Permaculture: Addressing Key Ecological Problems by Rethinking and Redesigning Agricultural Systems. Journal of Environmental Studies and Sciences, 6(2): 239–250. https://doi.org/10.1007/s13412-015-0254-8.

Wezel, A. & Silva, E. 2017. Agroecology and agroecological cropping practices. *In* A.Wezel, ed. *Agroecological practices for sustainable agriculture: principles, applications, and making the transition*, pp. 19-51. New Jersey, USA, World Scientific.

Coe, R., Hughes, K., Sola, P,. & Sinclair, F. 2017. Planned Comparisons Demystified. ICRAF Working Paper No 263. Nairobi, World Agroforestry Centre. DOI: http://dx.doi.org/10.5716/WP17354.PDF

HLPE. 2017. *2nd Note on Critical and Emerging Issues for Food Security and Nutrition*. A note by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/Critical-Emerging-Issues-2016/HLPE_Note-to-CFS_Critical-and-Emerging-Issues-2nd-Edition__27-April-2017_.pdf

Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., 2017. Fall Armyworm: Impacts and implications for Africa. CABI.

Rosset, P. & Altieri, M. 2017. *Agroecology: Science and Politics*. Agrarian Change & Peasant Studies. United Kingdom: Practical Action Publishing.

White, M. M. 2017. "A pig and a garden": Fannie Lou Hamer and the Freedom Farms Cooperative. Food and Foodways, 25(1), 20–39. https://doi.org/10.1080/07409710.2017.1270647

Bouis, H.E. & Saltzman, A. 2017. Improving nutrition through biofortification: a review of evidence from HarvestPlus, 2003 through 2016. Glob. Food Secur., 12: 49–58. http://dx.doi.org/10.1016/j.gfs.2017.01.009.

Moseley, W. 2017. A Risky Solution for the Wrong Problem: Why GMOs won't Feed the Hungry of the World. *Geographical Review*.

Peeters, A. & Wezel, A. 2017. Agroecological principles and practices for grass-based farming systems. *In* A. Wezel, ed. *Agroecological practices for sustainable agriculture: principles, applications, and making the transition,* pp. 293–354. New Jersey, USA, World Scientific.

Sanderson Bellamy, A. & Ioris, A. 2017. Addressing the Knowledge Gaps in Agroecology and Identifying Guiding Principles for Transforming Conventional Agri-Food Systems. *Sustainability*, *9*(3), 330. https://doi.org/10.3390/su9030330

Wezel, A. 2017. *Agroecological practices for sustainable agriculture: principles, applications, and making the transition*. New Jersey, USA, World Scientific. 485 p.

Korhonen, K., Kotavaara, O., Muilu, T., Rusanen, J. 2017 Accessibility of local food production to reginal markets – Case of berry production in Northern Ostrobothnia, Finland. European Countryside 9(4): 709-728

Mockshell, J. & Kamanda, J. 2017. Beyond the agroecological and sustainable agricultural intensification debate: Is blended sustainability the way forward? Deutsches Institut für Entwicklungspolitik, Bonn, Germany, 34 p.

Wittman, H. & Blesh, J. 2017. Food Sovereignty and Fome Zero: Connecting Public Food Procurement Programmes to Sustainable Rural Development in Brazil. *Journal of Agrarian Change*, 17: 81-105. doi:10.1111/joac.12131

Wittman, H., & Blesh, J. 2017. Food Sovereignty and Fome Zero : Connecting Public Food Procurement Programmes to Sustainable Rural Development in Brazil: Food Sovereignty and Fome Zero in Brazil. Journal of Agrarian Change, 17(1), 81–105. https://doi.org/10.1111/joac.12131

Brescia, S. 2017. *Fertile Ground: Agroecology from the Ground Up.* Groundswell International

Degefa, S. & Saito, O. 2017. Assessing the Impacts of Large-Scale Agro-Industrial Sugarcane Production on Biodiversity: A Case Study of Wonji Shoa Sugar Estate, Ethiopia. *Agriculture Basel*, 7(12).

Deere, C. D. 2017. "Women's Land Rights, Rural Social Movements, and the State in the 21st-century Latin American Agrarian Reforms." Journal of Agrarian Change 17: 258–278. doi:10.1111/joac.12208.

Stone, G.D. & Glover, D. 2017. Disembedding grain: Golden Rice, the Green Revolution, and heirloom seeds in the Philippines. *Agriculture and Human Values*, 34 (1), 87–102. doi:10.1007/s10460-016-9696-1

Loconto, A., Jimenez, A. & Vandecandelaere. E. 2018. Constructing markets for agroecology – an analysis of diverse options for marketing products from agroecology. Rome, Italy: FAO/INRA.

Saj, S., Torquebiau, E., Hainzelin, E., Pages, J. & Maraux, F. 2017. The way forward: an agroecological perspective for Climate-Smart Agriculture. Opinion Paper. *Agriculture, Ecosystems and Environment* 250 (2017): 20-24. http://dx.doi.org/10.1016/j.agee.2017.09.003

Cole, M.B., Augustin, M.A., Robertson, M.J. & Manners, J.M. 2018. The science of food security. NPJ, Science of Food, 2. Article number, 14 (2018). https://www.nature.com/articles/s41538-018-0021-9

de Hooge, I.E., van Dum, E., van Trijp, H.C.M. 2018. Cosmetic specifications in the food waste issue: Supply chain considerations and practices concerning suboptimal food products. Journal of Cleaner Production 183 : 698-709

Giraldo, O.F. & Rosset, P.M. 2018. Agroecology as a territory in dispute: between institutionality and social movements. *The Journal of Peasant Studies* 45 (3): 545-564.

Petersen, P. & Arbenz, M. 2018. Scaling up agroecology to achieve the SDGs: a political matter. Farming Matters 3/2018: 6-9. http://www.cultivatecollective.org/wp-content/uploads/2018/03/Farming_Matters_special_maart_2018_final.pdf

Ruel, M.T., Quisumbing, A.R., & Balagamwala, M. 2018. Nutrition-sensitive agriculture: What have we learned so far? Global Food Security. https://doi.org/10.1016/j.gfs.2018.01.002

Sibhatu, K. T. & Qaim, M. 2018. Farm production diversity and dietary quality: linkages and measurement issues. *Food Security*, 10(1): 47–59. https://doi.org/10.1007/s12571-017-0762-3.

Alamar, M.D., Falagan, N., Aktas, E. & Terrya, L.A. 2018. Minimising food waste: a call for multidisciplinary research. Journal of the Science of Food and Agriculture, 98(1): 8–11.

Migliorini, P. & Wezel, A. 2018. Converging and diverging principles and practices of organic agriculture regulations and agroecology. A review. *Agronomy for Sustainable Development*, 37: 63. https://doi.org/10.1007/s13593-017-0472-4

Nicholls, C. I., & Altieri, M. A. 2018. Pathways for the amplification of agroecology. *Agroecology and Sustainable Food Systems*, 1–24. https://doi.org/10.1080/21683565.2018.1499578

D'Annolfo, R., Gemmill-Herren, B., Graeub, B. & Garibaldi, L.A. 2017. A review of social and economic performance of agroecology, *International Journal of Agricultural Sustainability*, 15 (6): 632-644, DOI: 10.1080/14735903.2017.1398123

D'Annolfo, R., Gemmill-Herren, B., Graeub, B. & Garibaldi, L.A. 2017. A review of social and economic performance of agroecology, *International Journal of Agricultural Sustainability,* 15 (6): 632–644, DOI: 10.1080/14735903.2017.1398123.

Benyam, A., Kinnear, S. & Rolfe, J. 2018. Integrating community perspectives into domestic food waste prevention and diversion policies. Resources Conservation and Recycling, 134: 174–183.

Chappell, M.J. 2018. *Beginning to end hunger: food and the environment in Belo Horizonte, Brazil, and beyond.* Oakland, USA, University of California Press.

Demeke, M., Meerman, J., Scognamillo, A., Romeo, A. & Asfaw, S. 2017. *Linking farm diversification to household diet diversification: Evidence from a sample of Kenyan ultrapoor farmers*. ESA Working Paper No. 17–01. Rome, FAO.

Carriquiry, A., de Brauw, A., Meenakshi, J.V., Gilligan, D.O., 2012b. Introduction of b-carotene – rich orange sweet potato in rural Uganda results in increased vitamin A intakes among children and women and improved vitamin A status among. J. Nutr. 142, 1871–1880. http://dx.doi.org/10.3945/jn.111.151829.

Cucagna, M.E. & Goldsmith, P.D. 2018. Value adding in the agri-food value chain. International Food and Agribusiness Management Review, 21(3): 293–316.

Gollin, D. 2018. *Farm size and productivity; lessons from recent literature.* FAO, IFAD, ISPC/CGIAR, and the World Bank Expert Consultation: Focusing Agricultural and Rural Development Research and Investment on Achieving SDGs 1 and 2. 11 January 2018.

Gollin, D. 2018. *Farm size and productivity; lessons from recent literature.* FAO, IFAD, ISPC/CGIAR, and the World Bank Expert Consultation: Focusing Agricultural and Rural Development Research and Investment on Achieving SDGs 1 and 2. 11 January 2018.

Batello, C., Bezner Kerr, R.. Owoputi, I. & Rahmanian, M. 2019. Agroecology and nutrition: Transformative possibilities and challenges. In: *Sustainable Diets*. B. Burlingame and S. Dernini. CABI, Wallingford, Oxfordshire/Boston, MA., pp. 53-63.