Agroecology and Climate Change: A case study of the CCAFS Research Program

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Working Paper No. 313

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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About CCAFS working papers
Titles in this series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

About CCAFS
The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is led by the International Center for Tropical Agriculture (CIAT), part of the Alliance of Bioveristy International and CIAT, and carried out with support from the CGIAR Trust Fund and through bilateral funding agreements. For more information, please visit https://ccafs.cgiar.org/donors.

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Abstract

Climate change is challenging the sustainability of agricultural systems. Some authors argue that only an agroecological transformation of agricultural systems is the appropriate response to climate change issues. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), aims to catalyze positive change towards climate-smart agriculture (CSA), food systems and landscapes to meet the triple goals of food security, adaptation and mitigation. In this paper, we present agroecological principles as defined by various authors or institutions and question how they address climate change issues. Using FAO 10 elements of Agroecology as framework we investigate to what extent CCAFS is aligned with agroecological principles. To answer these questions, we used a combination of bibliographic study, interviews of CCAFS Flagship leaders and text mining method. Our main conclusion is that although agroecology was not a key concept in the design of CCAFS activities, on the ground many promoted practices where agroecological practices and several of the 10 FAO elements of agroecology were addressed but with a different perspective than the one promoted by the proponents of agroecology. To further improve or re-direct CCAFS activities with agroecological principles we recommended five main areas of intervention: to better include agroecological principles in the implementation of NDCs, to strengthen system thinking for food system transformation, to strengthen landscape-level activities, to develop projects on circular and solidarity economy, and to use CIS to support the implementation of agroecological practices.

Keywords

Agroecology, climate change, FAO 10 elements of agroecology.

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Contents

Acronyms

AR4D	Agricultural research for development
CCAFS	Climate Change, Agriculture and Food Security
CSA	Climate-smart agriculture
CIS	Climate information services
CSVs	Climate-smart villages
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas
ICTs	Information and communication technologies
MRV	Measurement, reporting and verification
NDCs	Nationally Determined Contributions
NGOs	Non-governmental organizations

Introduction

Today, 32% to 39% of the variability in crop yields around the world is due to the climate and translates into annual production fluctuations of 2 to 22 million tones for crops such as maize, rice, wheat and soybeans (Ray et al. 2015). This is expected to increase given climate change (Mbow et al. 2019). At the same time, agriculture and livestock contribute between 19% and 29% of global greenhouse gas (GHG) emissions (Vermeulen et al. 2012). In addition, FAO anticipates that by 2050, 60% more food will be needed for a world population that is growing and changing its consumption patterns through the consumption of more protein (Alexandratos and Bruinsma 2012).

Some authors argue that an agroecological transformation of agricultural systems is the only appropriate response to issues caused by climate change (Altieri et al. 2015; Sinclair et al. 2019). Agroecology is one of the options of sustainable land management (HLPE 2019). It is the application of ecological sciences to the study, design and management of sustainable agriculture (Altieri 1995). Integrated land-use systems that maintain species diversity, agrobiodiversity, the improvement of ecological processes and delivery of ecosystem services, the strengthening of local communities and recognition of the role and value of indigenous and local knowledge are core elements of agroecology (FAO 2018; Mbow et al. 2019).

There are two overall purposes of CGIAR's Research Program on Climate Change, Agriculture and Food Security (CCAFS); one is to marshal the science and expertise of the CGIAR System Organization and partners to catalyze positive change towards climate-smart agriculture (CSA), food systems and landscapes. The second is to position the CGIAR to play a major role in bringing to scale practices, technologies and institutions that enable agriculture to meet food security, adaptation and mitigation goals. CSA aims to find synergies between its three goals or pillars (sustainable productivity, climate change adaptation, and greenhouse gas mitigation) from local to global levels. Adopting a synergistic view to the three pillars of CSA facilitates improved distinction of CSA from other conventional agricultural production systems (FAO 2013).

There are controversies on whether CSA and agroecology are aligned. For Sinclair et al. (2019), while many agroecological practices are classified as climate-smart because they contribute to adaptation and mitigation, not all climate-smart practices follow agroecological principles. For example, no or minimum tillage practices, combined with the use of herbicides rather than mechanical options to destroy weeds, may be considered climate-smart but not agroecological. For Altieri et al. (2015), CSA pays too much attention to innovations and not enough to traditional practices and the underlying mechanisms that allowed existing systems to resist or recover from droughts, storms, floods, or hurricanes. Additionally, there is not enough consideration for these authors to the social resilience of the rural communities that manage such agroecosystems.

There is also skepticism about the efficacy of agroecology as a systematic approach that can sustainably feed a growing population. For Mugwanya (2019), the practices that agroecology promotes are not qualitatively different from those currently in use among smallholder farmers in sub-Saharan Africa. However, others question the added value of new frameworks such as agroecology rather than the improvement of existing principles for sustainability. But for Wise (2019), this argument is a defensive response to the failures of Green Revolution practices since agroecology promotes innovations around biological pest control, push-pull technology using specific crop mixes, participatory plant breeding, agroforestry and legume crop with a careful selection of tree varieties and density.

However, for some authors, these debates lead to an impasse between policy makers, implementers, and scientists and call for a pragmatic use of these concepts in order to go forward (Mockshell et al. 2019). Saj et al. (2017) proposed to explore the complementarity between both concepts, agroecology having produced extensive literature on the resilience of farming systems and climate-smart agriculture on the role of institutions that support change in agricultural systems.

In this paper, we present agroecological principles and how they address climate change issues. We then examine to what extent CCAFS is aligned with agroecological principles. We conclude with recommendations for improving the application of agroecological principles in a future climate change research program for agricultural development.

Agroecology and climate change framework

Agroecology core-shared principles

There is no one universal definition for agroecology, however concepts of complexity, context-specificity, bottom-up and territorial or landscape processes are at the core of shared agroecology principles. Indeed, recent years have seen the multiplication of definitions of agroecology with nuances depending on the authors, institutions or organizations, highlighting its dynamic aspect (HLPE 2019). Nonetheless, there is a consensus that agroecology embraces three dimensions: a transdisciplinary science, a set of practices and a social movement (Wezel et al. 2009; Wezel, Silva 2017; HLPE 2019; FAO 2018)

The HLPE (2019) report defines an agroecological approach to sustainable food systems for food security and nutrition as follows:

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

Thus, agroecology provides possible transition pathways towards more sustainable food systems, based on a holistic and systemic approach (IPES-Food 2016). During its historical evolution, agroecology’s focus went from the field, farm and agroecosystem scales to encompass the whole food system over the last decade.

Bridging ecological and social dimensions, and rooted in sustainability, agroecological approaches aim to transform food and agriculture systems, and address the root causes of problems. Proponents believe it is people-centered, knowledge-intensive, and will provide holistic and long-term solutions as aimed by the 2030 Agenda (FAO 2018). Agroecology particularly contributes to no poverty (SDG1), zero hunger (SDG2), good health and

wellbeing (SDG3), decent work and economic growth (SDG8), responsible consumption and production (SDG12), climate action (SDG 13) and life on land (SDG 15) (FAO 2019).

Encompassing aspects related to the three pillars of sustainable development (environment, social and economic), several sets of agroecological principles were developed by different actors to characterize inherent properties of agroecology.

Building on the scientific foundation of Altieri (1995) and Gliessman (2004) and complemented by workshop discussions during multi-actor regional meetings (governments, civil society, research and the private sector) on agroecology from 2015 to 2017, FAO developed the 10 elements of agroecology. The 10 elements of agroecology give member countries a framework for understanding and operationalizing agroecology. The 26th Session of the Committee on Agriculture (COAG) supported the Ten Elements of Agroecology, as presented by FAO, as a guide to one of the ways to promote sustainable agriculture and food systems (FAO 2019). They provide an overall framing of important properties of agroecological systems and approaches, as well as key considerations in developing an enabling environment for agroecology.

1. Six elements relate to the description of common characteristics of agroecological systems, foundational practices and innovation approaches: **Diversity; synergies; efficiency; resilience; recycling; co-creation and knowledge sharing.**
2. Two relate to context features: Human and social values; culture and food traditions.
3. And two relate to the enabling environment: Responsible governance; circular and solidarity economy.

In the next section, we explain how climate change is taken into consideration into these principles.

Climate change in agriculture: Core-shared principles

The relationship between climate change and agriculture has been framed in terms of both the threat of climate change impacts on agriculture and the role agriculture can play in adaptation to and mitigation of climate change impacts. For comparison with agroecology principles, we focus here on the principles of climate-smart agriculture (FAO 2017):

4. sustainably increase agricultural productivity and the incomes of agricultural producers;
5. strengthen the capacities of agricultural communities to adapt to the impacts of climate change, including disaster risk management;
6. reduce and/or remove greenhouse gas emissions.

While CSA ideally seeks to meet all three objectives, there may be more focus on mitigation or adaptation. Understanding the impacts of CSA at multiple scales requires knowing whether plot, farm, household, village, landscape, national or international value chains are relevant to managing agricultural outcomes.

Transformations for climate change adaptation need to consider the current climate as well as a range of future possible climate scenarios. Interactions with other agricultural and livelihood risks (e.g. pests and diseases, market failure, pandemics) and natural resource sustainability also should be considered. Transformations for climate change mitigation usually require mitigation to be a co-benefit of agricultural practices that deliver improved yields, adaptation or other benefit to be attractive to farmers.

The UNFCCC Paris Agreement includes countries' pledges to reduce and adapt to climate change. The Nationally Determined Contributions (NDCs) to the Paris Agreement showed that countries view agriculture as a priority sector for adaptation and disaster risk management. More than 100 countries also included mitigation targets in the agriculture sector (Richards et al. 2016).

Correspondence between elements of agroecology and climate-smart agriculture

Various authors have highlighted that each of the FAO elements is relevant to respond to the challenges posed by climate change (HLPE 2019; Sinclair et al. 2019,).

Diversity: diversity in agroecological systems includes crop diversification, maintaining local genetic diversity, animal integration, soil organic matter management, water conservation and harvesting, and livelihood diversification that reduces vulnerabilities to climate variability is key to address climate change.

Synergies: agroecological practices aim to enhance positive ecological interaction, synergy, integration, and complementarity among the elements of agroecosystems (plants, animals, trees, soil, water) that give opportunities to build synergies and manage trade-offs across the multiple objectives of food security and climate change adaptation and mitigation.

Efficiency: this principle aims to a gradual reduction in the use of pesticides and synthetic fertilizers, which are replaced by biological methods. This avoids the climate-damaging emissions that arise when these substances are produced and used.

Resilience: it is a key outcome of agroecological systems based on the implementation of a various other principles in particular spatial and temporal diversity but also all the traditional knowledge of smallholders, family farmers, or indigenous people and their associated social networks that helped them to manage past and recent climate risks.

Recycling: the recycling of biomass, with a view to optimizing organic matter decomposition and nutrient cycling over time plays a key role to improve the efficiency in the use of resources; it also decreases wastes and costs of production with co-benefits in terms of limitation in GHG. Recycling delivers multiple benefits by closing nutrient cycles and reducing waste. Recycling also permits producers to save costs on inputs, reducing their vulnerability to price volatility and climate shocks.

Co-creation and sharing of knowledge: ancestral knowledge is seen as the foundation for actual and future agricultural innovations and technologies to deal with climate change given in particular the ability of traditional farming systems to recover from recent and past climate challenges, new knowledge is necessary, but attention is paid on power asymmetries between scientists and farmers.

Human and social values: agroecology pays attention to social lock-ins and power relations. By building autonomy and adaptive capacities to manage their agro-ecosystems, agroecological approaches empower people and communities to become their own agents of change and overcome the various challenges they must deal with poverty, hunger, malnutrition including climate change.

Culture and food traditions: agroecological systems are based on the culture, identity, tradition, of local communities that provide culturally, healthy, diversified, seasonally

appropriate diets. There are consequently the foundations for the design of innovative systems able to cope with climate change.

Responsible governance: Aims at establishing supportive national and local frameworks that reduce lock-ins at local level, recognize and support the needs and interests of family farmers, smallholders, in order to avoid maladaptation to climate change.

Circular and solidarity economy: This principle aims to reconnect producers and consumers and provide innovative solutions for living within our planetary boundaries while ensuring the social foundation for inclusive and sustainable development. Particularly this means to promote fair solutions based on local needs, resources and capacities, creating more equitable and sustainable markets. Strengthening short food circuits can increase the incomes of food producers while maintaining a fair price for consumers; increasing the economic resilience of both producers and consumers. Applied to question of climate change this means tackling technical innovations (e.g., decreasing wastes) and organizational innovations (labels, short circuits) that will improve resilience to climate change with co-benefits in terms of mitigation.

Climate change poses multiple threats to the food system and at different stages of the food chain. To tackle these complex set of risks, the principles of agroecology are not only relevant but are necessary to achieve the goals of adaptation and mitigation. Particularly, from a technical perspective, the diversity principle (both in term of crop production and economic activity) is fundamental to improve the resilience of farming systems and livelihoods; whereas the recycling and efficiency principles can have clear co-benefits in terms of mitigation. Additionally, the management of synergies between components of agrobiodiversity will also ensure synergies between adaptation and mitigation. However, neither adaptation nor mitigation will be successful without building on human values, culture and food traditions or working on the enabling environment (responsible governance, and circular and solidarity economy).

Agroecology is a dynamic process

Some authors emphasized the pathways from conventional to agroecological systems. For example, Hill (1998) proposed a conceptual framework called “Efficiency-Substitution-

Redesign" (ESR) (1998) to analyze the different stages of the transition to agroecological systems. This framework makes the distinction between:

1) the efficiency stage, characterized by changes in conventional systems to reduce the consumption and waste of costly and scarce resources (e.g., optimal timing of operations or by banding fertilizers),

2) the substitution stage, where environmentally disruptive inputs are replaced by those that are more environmentally benign (e.g., purchase of organic fertilizers instead of mineral fertilizers), and

3) the redesign stage where design and management approaches are used to rely more strongly on ecological processes and ecosystem services instead of external inputs.

Duru et al. (2014) used this framework to make the distinction between a weak agroecology (efficiency and substitution stages) and a strong agroecology (redesign stage). Gliessman (2016) proposed two additional steps to this ESR framework which correspond to changes in consumption patterns, civilization and development; these steps are set as necessary for the transformation of the food systems (Figure 2).

Methods

Overview of CCAFS program

Flagship Program 1: Priorities and Policies for CSA

FP1 aims to assess how enabling policy environments and priority setting for targeted investment can support the scaling of interventions, contributing to food and nutritional security and poverty reduction under climate change. Objectives are:

a) improved priority setting, trade-off analyses, and foresight;

b) improved understanding of effective enabling policy environments;

c) more evidence as to how CSA at scale can contribute to food security; and

d) effectively informed investment decisions.

Primary target beneficiaries are climate-vulnerable and food insecure groups, including smallholder men and women, and (via national to global policy influence) the urban poor and broader populations in target countries.

Flagship Program 2: Climate-Smart Technologies and Practices

FP2 will work with partners to test, evaluate, promote and scale up CSA technologies and practices that meet the needs of farmers – including women and marginalized groups. Its purpose is to build adaptive capacity and resilience to climate variability and change, while increasing food availability and generating mitigation co-benefits. This will be achieved by integrating and applying the best and most promising methods, tools and approaches for equitable local adaptation planning and governance and developing innovative incentives and mechanisms for scaling up.

The primary target beneficiaries of FP2 are climate-vulnerable, food insecure and poor groups (smallholder farmers and women in particular). Research will also benefit development agencies from grassroots through to national scales, as well as local and subnational institutions involved in agricultural planning, and the private sector that can support scaling up. Climate-smart villages (CSVs) have been established as platforms where

CSA technologies and practices, climate information services, local development and adaptation plans and supportive institutions and policies are tested (Figure 1).

Flagship Program 3: Low-Emissions Development

FP3's overall goal is to test the feasibility of reducing agricultural GHG emissions at large scales while ensuring food security in developing countries. Objectives are to provide evidence and tools for (1) improved estimates of emissions from Low Emissions Development (LED) in smallholder farming; (2) impacts of LED on emissions, food security and other outcomes and resulting priorities and (3) conditions enabling LED at large scales among smallholder farmers and in major supply.

The primary beneficiaries of FP3 are smallholder farmers for whom LED practices can contribute to food security and climate resilience by increasing yields, reducing inputs and improving natural capital. Research will also benefit national LED efforts through better emissions estimates, technical capacities to implement and monitor LED, and policy development.

Flagship Program 4: Climate services and safety nets

FP4 aims to work with partners to develop climate information and advisory services that support farmers, weather-related insurance that protects farmers and increases investment in CSA, food security early warning and safety net systems that protect livelihoods from extreme events, and climate informed planning by governments and by development organizations. These services will provide an enabling environment for smallholder farmers to transition towards more climate-smart production systems and climate-resilient livelihood strategies, while protecting them from climatic extremes. Research will develop the knowledge, methods, capacity and evidence needed to design, target and implement these interventions effectively at scale.

Gender and social inclusion (GSI)

CCAFS cross cutting GSI program seeks positive development outcomes for men, women, and youth to ensure households and communities are more resilient under climate change. This includes informing, catalyzing and targeting solutions for women, men, and youth in communities to increase their control over productive assets and resources (e.g., climate

information, novel climate finance), and increase participation in decision-making (e.g., in local and national climate adaptation strategies). The GSI program assesses the impacts of climate change on livelihood strategies and food systems with women, men and youth to enhance their knowledge and capacities; promotes the transformation of gender roles and relations, and women's greater equality; and strengthens institutions to increase the agency of women, men and youth. Examples include research on agroecology and resilience in Nicaragua (Gumicio 2017; 2018), joint farmer-led technology development (Waters-Bayer 2015) and working with women's groups on baobab management Daga-Birame, Senegal (Ouédraogo 2018).

A multi-regional program

CCAFS focuses on five regions: Latin America, West Africa, East Africa, South Asia and Southeast Asia. The regional hubs, with regional program leaders, remain the central mechanism for connecting research and policy engagement across all FPs. Regional program leaders have developed outcome targets for each of the countries with CCAFS projects and engagement strategies. For outcomes related to organizational and institutional change, this included listing specific organizations that the CCAFS theory of change will target and estimating the likelihood of achieving change. Similarly, they examine the likely countries where flagships can achieve a specified outcome.

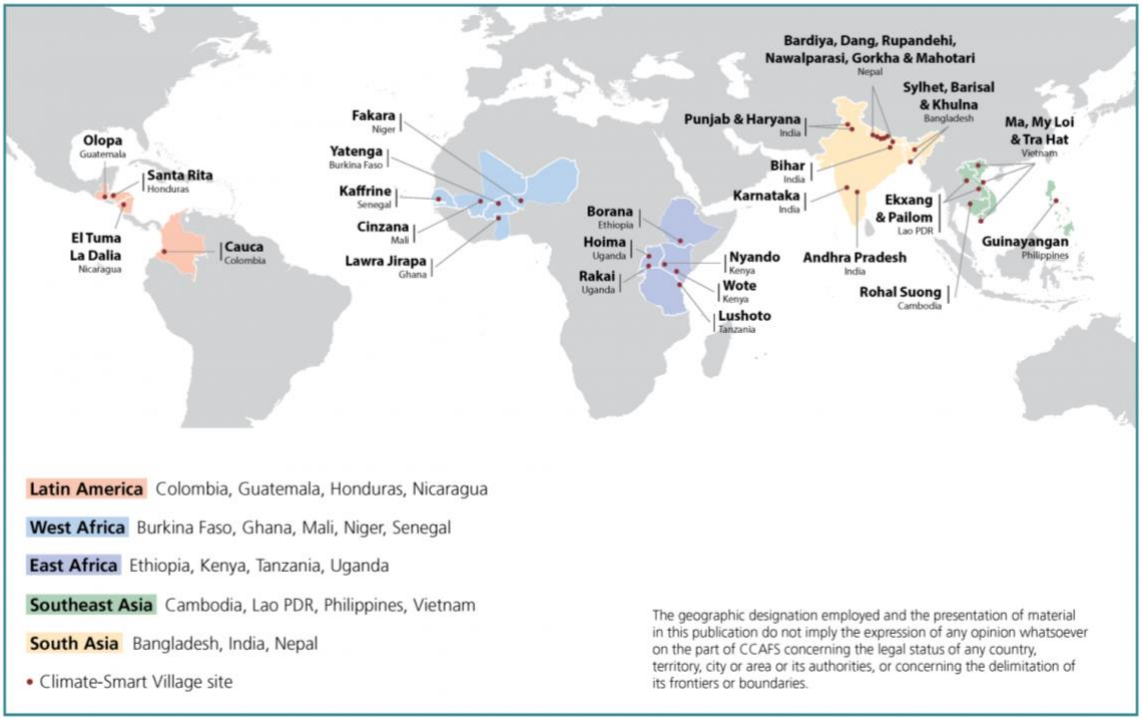

Figure 1. Location of the climate-smart villages (CSVs) agricultural research for development sites. This shows the CCAFS-facilitated CSV sites. There are also partner-facilitated sites, numbering in their hundreds, where partners bring together various climate-smart solutions.

Literature review

To have a first overview of the diversity of CCAFS research outcomes and be able to locate agroecology in this panorama we conducted a literature review. We used Scopus database searching for all articles with a CCAFS affiliation. We found 315 peer-reviewed scientific articles (these do not include working papers, policy brief, reports) over the period 2009-2020. We exported the title, abstract, key words and cited references of those articles and analyzed using cortex manager (www.cortext.net) text mining software. We selected the first 300 most occurring terms, merged identical terms appearing in different spelling and performed a network analysis with the first 75 most occurring terms within the titles, key words and abstracts. The result is shown in Figure 3.

Survey to CCAFS leaders

For an in-depth description of the alignment between CCAFS activities and agroecological principles, we interviewed the four CCAFS Flagship Leaders in charge of coordinating the

strategic implementation of the project and two regional leaders in charge of implementing the various dimensions of CCAFS on the ground.

An open-ended discussion was conducted around seven questions:

7. What is agroecology for you?
8. Have you considered agroecological principles in the design of your flagship?
9. How has your flagship contributed to agroecological principles?
10. Identify 2-3 projects/papers that contributed to agroecological principles
11. What could be done in the future to better contribute to agroecological principles: e.g. key research questions, key partners, outcome and impact monitoring, priority systems?
12. Did grassroots/civil society organizations or NGOs play a role in the activities of your flagship?
13. If yes, in which way? If not, why?

The projects or articles that project leaders found most aligned with CSA principles were reviewed (Question 4) and further analyzed according to the FAO 10 elements of agroecology (Table 1).

Conceptual framework

We analyzed the inputs of the surveys using the combined lens of the 10 elements proposed by FAO and the 5 steps proposed of Gliessman (2016) as represented in Figure 2.

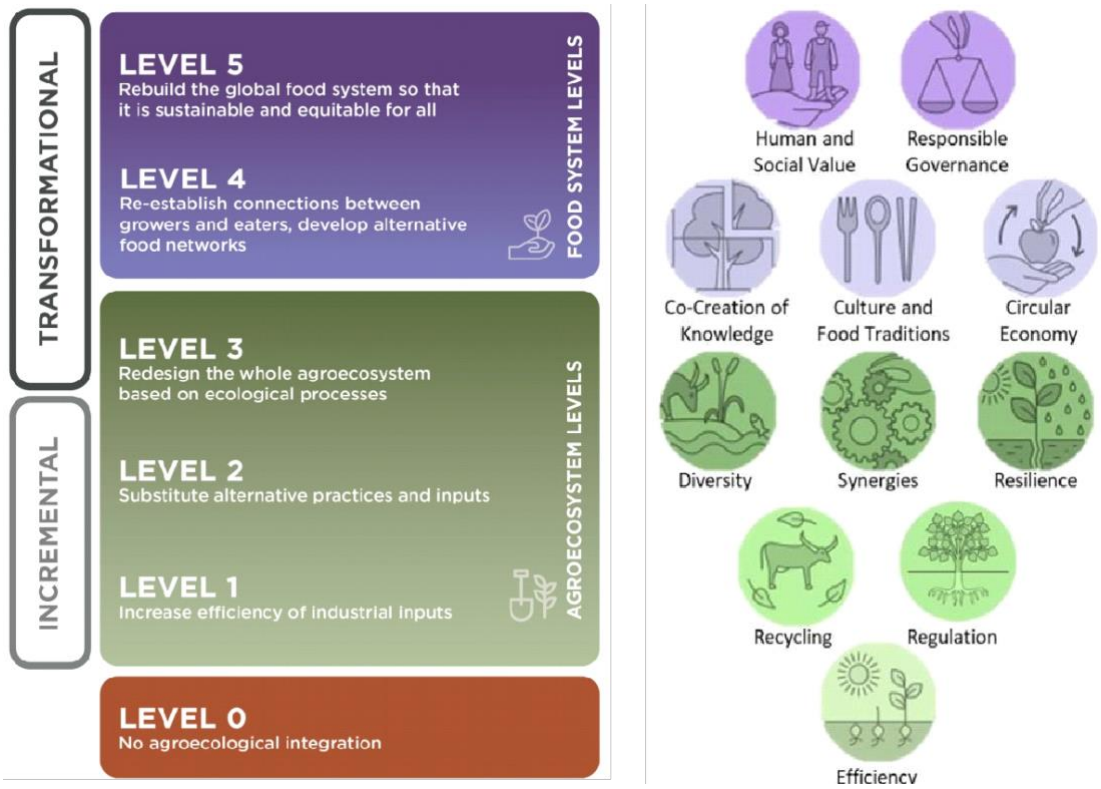

Figure 2. Conceptual framework used in this study: the 10 elements of agroecology from FAO and the 5 levels of transition towards SFSs (Gliessman, 2007).

Source: Biovision 2020, https://www.agroecology-pool.org/, inspired by (HLPE 2019).

Results

Results of the systematic review

The results are provided in Figure 3. Network mapping revealed six clusters of terms with varying sizes reflecting their importance and representing the main areas of CCAFS' work. Each cluster of terms is embedded within a circle of different colors, the dominant terms in clusters are in bold and the terms linking different clusters between them are in bold and italic. The thickness of the lines joining the terms reflects the level of the link between the terms (thick line = strong link). With descending importance, we can observe the following clusters: i) **blue**: climate change, farming systems; ii) **grey**: climate change mitigation, GHG emissions; iii) **brown**: future climate, cropping systems; iv) **red**: climate-smart agriculture; and v) **green**: two small clusters around breeding and crop/genetic resources.

In the brown cluster, the term 'future climate' is the dominant term linking other terms together such as 'soil erosion', 'genotype adaptation'; and connecting to the cluster about breeding via the term "phaseolus vulgaris" and to the blue directly via the term 'fertilizer application' and indirectly via the term 'management practices'.

The blue cluster (climate change, farming systems) is linked to the red one via the term 'smart agriculture.' The terms in the grey cluster are very close to each-other, reflecting the that these terms are very related to each-other; it links to the blue cluster (climate change, farming systems) via the terms 'nations/framework/conventions' and indirectly via the term 'Paris agreement'.

The term 'participatory approach' (low occurrence) is found at the bottom of the red (CSA) and is weakly linked to 'climate risks' and 'climate services.'

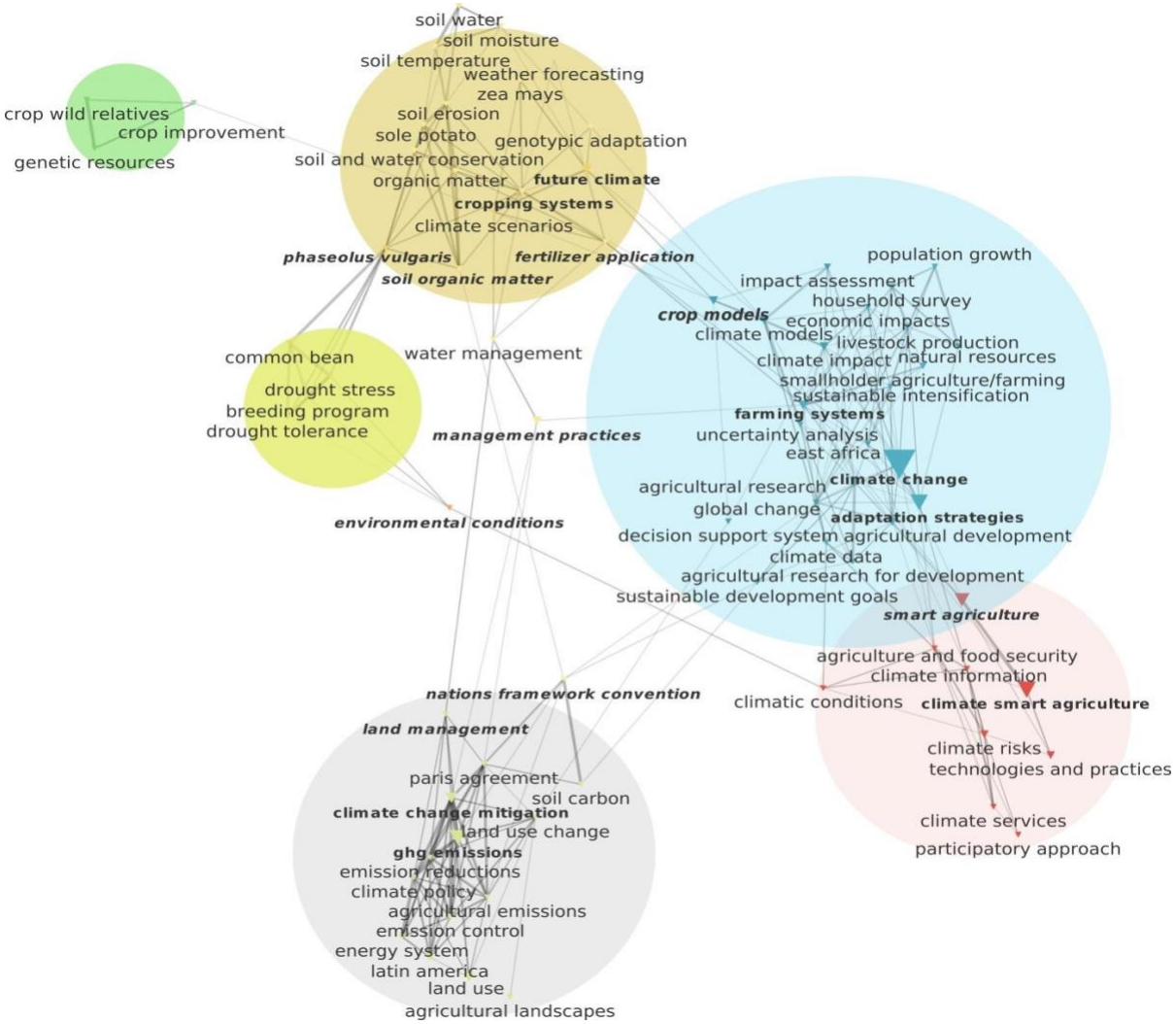

Figure 3. Network analysis of the 75 most recurrent terms in CCAFS publications in Scopus database.

In-depth analysis of regional and flagship activities and results

The survey conducted with the flagship and regional leaders highlighted their various conceptions on agroecology: from a very technical vision to a broader recognition of its socio-political dimension. They all confirmed that agroecology was not a guiding principle in the design of their flagships. The guiding principle was clearly CSA. Other concepts were key such as resilience or risk management. For some of them agroecology is broader than CSA because it includes nutrition issues. Conversely, for others it is more restricted, because it focuses on the local level. They explained part of the distance between their flagship and agroecological principles by their scale of intervention or their main entry point. However, they all identified alignments between their activities and some of the agroecological concepts. Particularly the platforms that were built to involve a diversity of stakeholders at

various scales, gender inclusion, and the nature of most of the practices that were tested on-farm, especially in the climate-smart villages. They identified gaps in the current CCAFS research such as the lack of consideration of the entire food systems and, in particular, the lack of analysis of linkages between farmers and consumers at territorial scale, nutrition issues and circularity. They also expressed some criticisms on agroecology such as the lack of evidence on the performances of agroecological practices or the lack of clear definition.

The deeper analysis of the document shared by these leaders allowed us to map CCAFS activities under FAO 10 agroecological elements (Table 1).

Table 1. Mapping of CCAFS activities to the FAO 10 elements

	Flagship 1	Flagship 2	Flagship 3	Flagship 4	Regional leader West Africa	Regional leader Asia
Diversity	Enabling policies to promote diversity (e.g., seed systems)	Portfolios of practices promoted in the different sites	Improving agroforestry Cattle and coffee certification in Brazil	Tailored climate information promotes diverse management practices and livelihoods	portfolio of practices with a focus made on the farm diversification	
Resilience	Enabling policies to promote resilience (seed systems, insurance, etc.)	Used to assess the adaptation pillar of CSA	Criteria developed for climate bonds criteria.	Used to measure the effectiveness of climate services	Used to assess the adaptation pillar of CSA	Used to assess the adaptation pillar of CSA
Synergies	Enabling policies to promote	Between the three pillars of CSA	Analysis of adaptation and mitigation synergies	Between climate information, advisories, inputs, loans, insurance	Between the three pillars of CSA	Between the three pillars of CSA
Efficiency		Efficient use of organic and mineral fertilizers Efficient use of water	N and water efficiency in rice and cereal systems	More efficient management practices based on trainings on climate information	Efficient use of organic and mineral fertilizers Efficient use of water	Efficient use of organic and mineral fertilizers Efficient use of water
Recycling		Practices based on the recycling of crop residues and manure	Animal waste recycling for horticulture Food loss and waste reduction		Practices based on the recycling of crop residues and manure	Practices based on the recycling of crop residues and manure

Co-creation and sharing of knowledge	Science-policy dialog platforms involving a plurality of actors (NGOs, Science, Donors, Policy makers)	CSV approach as a space to co-design	Development of MRV approaches with country governments; AgMRV website; Vi Agroforestry institutional sustainability guidance	Technical and endogenous knowledge on climate were shared to co-design agroclimatic information linking local and national stakeholders	CSV approach Co-design of climate information services Information Science-Policy dialog platform	CSV approach
Human and social values	Gender inclusion in policies	Gender inclusion in prioritization of practices and assessment of outcomes	Gender strategy and analysis	Gender inclusion in the targeting of services and in the assessment of outcomes	Gender inclusion in prioritization of practices and assessment of outcomes	Gender inclusion in prioritization of practices and assessment of outcomes
Culture and food traditions			Diet change, alternative meat to reduce GHG emissions		New crops included in traditional meals	
Responsible governance	Science-policy dialog platforms involving a plurality of actors (NGOs, Science, Donors, Policy makers)		Nationally Appropriate Mitigation Action support to countries; support to Koronivia Joint Work on Agriculture (UNFCCC)	Science policy-dialog Co-production of climate services	Science policy-dialog Co-design of climate information services (e.g. through multi-disciplinary working groups)	Co-design of climate information services
Circular and solidarity			Circular bio-economy on peri-urban agriculture proposal for 2-Degree Initiative		Processing by women groups of non-timber forest products (e.g. baobab fruits, tamarind fruits) for local/internal markets	

Discussion

What are the linkages between CCAFS' activities and agroecological principles?

If agroecology was not a key concept in the design of CCAFS activities, on the ground many promoted practices where agroecological practices and several of the 10 FAO principles were addressed. However, it is not a surprise to find overlapping practices between CSA and agroecological approach given the diversity of activities that has been conducted under this program. Furthermore, the way to address each of these principles by the CCAFS program presents some convergence and divergence with the proponents of agroecology.

Efficiency, recycling, co-creation and sharing of knowledge were the most prominent principles of the FAO agroecological framework in CCAFS activities. Indeed, many of the tested practices tried to improve the efficiency of water and nutrient usage (soil and water conservation technologies, microdosing of fertilizers, etc.). Compost was one of the most promoted practices across sites based on the recycling of crop residues or manure production. Co-creation and sharing of knowledge at various scales was quite present with the different platforms that have been supported at local and national levels for the co-design of innovative practices in CSV, the design of agro-climatic information, improved decision-making, CSA indicators or measurement, reporting and verification (MRV) approaches.

Resilience, diversity, human and social values or responsible governance were also included, but with a different perspective than the one promoted in the literature on agroecology. Indeed, even if the concept of resilience was key and used as a metric of adaptation, it was mostly considered from its environmental and engineering components (Antwi et al. 2014). The socio-economic resilience of existing farming systems through the exploration of synergies between on-farm and off-farm activities and the resilience of agroecosystems to pests and diseases were not fully addressed. For the diversity principle, it was mostly considered at plot scale through the design of portfolios of practices or crop diversification. Diversity was not taken into consideration at landscape scale: maintenance of habitat connectivity to ensure pollination and pest control (that will be exacerbated with climate

change), targeted location of activities within the landscape to improve flows of biomass or maintain critical carbon stocks (Harvey et al. 2014). In some specific CSVs such landscape arrangements have been explored (example of forest reserve in the Kaffrine CSV, Figure 1); however, the focus was mainly on experiments at plot and farm scale.

The principle of human and social values was mainly considered through the lens of gender inclusion. Eriksen et al. (2019) showed that gender inclusion can potentially open spaces for transformation of farming systems across personal, practical and political spheres. However, other social lock-ins and associated power relations could be better explored such as access to land or other natural resources, access to knowledge, access to networks (networks driven by civil society actors, such as producer organizations, communities, and social movements) since they play a key role in agroecological transition (Anderson et al. 2019).

The responsible governance principle was addressed through various platforms (science-policy dialog, multidisciplinary working groups for the co-creation of agroclimatic information, multi-stakeholder workshops on MRV) and favored exchanges between a plurality of stakeholders at national and local levels and led to success stories in terms of climate policy design (Zougmoré et al. 2019). However, a remaining challenge (for CCAFS and more generally for most climate change research programs) is how to improve synergies between climate change and economic development policies that may use diverging incentives for agriculture.

Culture and food traditions were addressed in CCAFS activities, since food security is one of the key pillars of CSA. However, it was mostly considered from a production perspective and many of the tested practices aimed to improve the supply of food through improved varieties, better management of soil and water resources, new crops, and plant-based alternatives to meat, etc. The implication of these changes on nutrition or modes of consumption were barely assessed.

Circular and solidarity is an emerging topic in CCAFS activities that was mentioned in one project of Flagship 3. In parallel, through the involvement of some NGOs, particularly in Latin America, some activities have contributed to the development of short circuits; such activities could be strengthened by exploration of the benefit of participatory labelling involving civil society to incentivize transformation of agricultural systems.

Regarding the different levels defined by Gliessman (2016) and taking into account the focus made on production, the work conducted by CCAFS mostly considered levels 1 to 3[1]. The involvement of NGOs in some CSVs permitted to take into account other issues than production (e.g. health, consumption) and some policy analyses have also addressed issues such as diet change and nutrition. However, there is room to improve CCAFS' activities and to support transformation of agricultural systems. Gliessman (2016) suggested re-establishing a more direct connection between those who grow our food and those who consume it. Food system transformation occurs within a cultural and economic context, and this transformation must promote the transition to more sustainable practices.

Farmers need support to move through Levels 1-3 by citizen prioritizing locally grown and processed food (such as food citizenship[2] movement) and by countries (public procurement of locally grown and transformed food for canteens of schools and governmental agencies). This support becomes a kind of "food citizenship" and is a force for food system change. Communities of growers and eaters can form alternative food networks around the world where a new culture and economy of food system sustainability is being built. Food once again must be grounded in direct relationships. An important example is the current food "relocalization" movement, which grows networks of farmers' markets, supports community agriculture schemes, consumer cooperatives, and other more direct marketing arrangements that shorten the food chain.

Propositions to better contribute to agroecological principles

The mapping of CCAFS activities according to the agroecological principles and the discussion with the flagship and regional leaders allowed us to identify specific areas for improvement or reorientation of on-going or future CCAFS activities to better align to agroecological

[1] Level 1: Increase the efficiency of industrial and conventional practices to reduce the use and consumption of costly, scarce, or environmentally damaging inputs. Level 2: Substitute alternative practices for industrial/conventional inputs and practices. Level 3. Redesign the agroecosystem so that it functions on the basis of a new set of ecological processes.

[2] Food Citizenship is a movement of individuals and organizations across the food system. It is rooted in an increasingly widely shared belief that people can and want to shape the food system for the better, given the right conditions (https://foodcitizenship.info/about/).

principles. These five areas of improvement need to be handled in parallel to support the transition to agroecological systems addressing climate change. CCAFS activities occur across broad and heterogeneous agroecosystems settings (Figure 1) giving the ability to synthesize across them. From this body of work, one can build on CCAFS' strengths particularly on CSVs, science-policy dialog or digital climate information services for pursuing and including strengthening an agroecological agenda.

1. Strengthening agroecology in nationally determined contributions (NDCs)

At COP 23 in 2017, the collaborative process of the Koronivia Joint Work on Agriculture (KJWA) gave priority to the objective to "develop and implement new strategies for adaptation and mitigation within the agriculture sector" (St-Louis et al. 2018). This decision is opening opportunities for future activities integrating agriculture and climate change issues, including funding by donors and private sector initiatives (Biovision and IPES-Food 2020).

At the national level, an analysis of the NDCs by Darmaun et al. (2020), showed that out of 136 NDCs analyzed, 17 countries[3] (12.5 %) explicitly mention agroecology. For these 17 countries, 15 of them see agroecology as an intended adaptation strategy while only 6 countries see it as contributing to mitigation. In addition to the 17 countries explicitly mentioning agroecology as either an adaptation or mitigation strategy or both, many countries mention agroecological approaches by highlighting some of the elements of agroecology. The elements of agroecology highlighted most prominently are related to production aspects (diversity, efficiency, recycling, resilience and synergies), (Darmaun et al. 2020). CCAFS actively supported various countries in the formulation of their NDCs. A specific investment could be done to incentive countries to align their NDCs more explicitly with agroecological principles and support the development of metrics for assessment of performance. Also, CCAFS' expertise in the analysis of climate finance could be aligned with and assessed for agroecological principles.

[3] Burundi, Comoros, Ethiopia, Rwanda, Seychelles, Tunisia, Gambia, Togo, Côte d'Ivoire, Nigeria, Central African Republic, Chad, Democratic Republic of Congo, Honduras, Venezuela, Afghanistan.

2. Strengthening system thinking for transformation of food systems

Climate change affects not only the production but the entire food system while agroecological principles support integrative thinking between biodiversity, nutrition, climate change, and more globally various environmental challenges (e.g. health, energy). Both concepts invite consequently to system thinking for transformation of food systems. This requires the inclusion of all actors of the food system that have potential role in addressing climate change (or in taking on new opportunities such as more transformation of food at local and national level, renewable energy services) and actors from other sectors (biodiversity, soil health, nutrition, energy). This system thinking must be applied at socio-political level but also at technical level.

At socio-political level, on-going work in CCAFS aims to understand policy mixes or the combination of policy instruments (Howlett and Rayner 2007) across scales and among economic sectors (Cash et al. 2006), to tackle climate change (Le Coq et al. 2019) and the trade-offs and synergies between climate change, risk management, agriculture or food security policies. More ambitious policy mixes could be tackled to favor synergies between various environmental challenges (health, climate, biodiversity) and the various actors/sectors of the food systems at national and local scales. The existing science-policy dialog platforms could then rely on such analyses to identify how to improve this system thinking in policy implementation.

At technical level, this implies for CCAFS to:

1. broaden the activities and practices tested beyond the focus on production/availability of food, in particular to nutrition and health issues.
2. ensure the sustainability of production base: biodiversity, soil, water, land, energy.
3. integrate natural resources concerns related to landscape planning.
4. promote local and short food circuits to better connect food production and consumption.

This could eventually build on the existing multi-stakeholders platforms developed in the CSV (Jagustović et al. 2019).

3. Strengthen existing works at landscape scale

Building on current work on climate-smart landscapes (Harvey et al. 2014; Scherr et al. 2012) we propose to expand the work at landscape scale. This scale is relevant to take into account both the socio-technical and socio-ecological systems in which farming systems are embedded at local level and that are key to promote agroecological transition.

The socio-technical system can be defined as the set of actors and rules (e.g. user groups and practices, markets, industry structure, policy), of social values, and ideologies that influence the emergence or not of a radical innovation (Geels 2002; 2005). Considering the socio-technical system at landscape scale permits research to consider the various actors involved not only in the production stage but also in the value chain (transport and marketing of food production); and to define a broader set of solutions to address climate change, including incentives for private sector transitions to agroecology.

The socio-ecological system can be defined as the interactions between a socio-technical system and the natural resources (Duru et al. 2015). Therefore, strengthening existing work at landscape scale will allow designing not only practices that improve outcomes at plot and farm scales, but also practices that maintain habitat connectivity (to ensure pollination and pest control), that favor biomass flows, or that maintain critical carbon stocks with benefits in terms of resilience and mitigation. For CCAFS, this also means investing further in activities that aim to improve both technical innovation at landscape scale (corridors, forests reservoirs, etc.) and organizational innovation (farmer groups, land-use planning, etc.) aiming to improve networking, equitable access to local natural resources, and governance.

4. Circular and solidarity economy

We have seen that the circular and solidarity economy principle is relatively new in CCAFS activities. Expending current work means co-designing with stakeholders technical and organizational innovations permitting to support circularity. This means developing organizational innovations (participatory labels, short circuits) permitting fair linkages between producers and consumers that could be supported using Information and communication technologies (ICTs). This also means technical innovations at farm and landscape scale aiming at decreasing biomass, energy and food waste (this last aspect can be

built on the extensive work already addressed in Flagship 3) from production to consumption (technologies to decrease harvest and post-harvest wastes or that permit better storage of grains, improved recycling of wastes for organic fertilizer production or energy, distribution of food surpluses for aid). This also means investing further in cities and peri-urban agriculture that have the potential to shorten food circuits but that have specific challenges (vertical agriculture, services and disservices (noise) for urban citizen).

5. Digital climate information services to support agroecological transition

Agroecology is knowledge intensive and require information and data to be specific to the local context. Therefore, digitalization may play a key role for democratization of knowledge and for reaching many actors of the food system. Climate change is an issue that requires a global perspective to solve local problems; hence, decentralizing digital tools can be crucial for collecting and sharing locally pertinent information in transparent ways. Improving access of women and the most vulnerable farmers to digital resources and integrating climate information services (CIS) with other digital platforms will be important. Building on CCAFS work, which has brought together institutions at the national and local levels, but also scientific knowledge on climate forecasts and endogenous knowledge (bioindicators) to produce (CIS), we propose examining the use of digital climate-informed advisories to meet the knowledge needs of agroecology. To really embrace an agroecological approach, the use of CIS should go beyond improving the efficiency of conventional agriculture. In fact, CIS should be used to guide the implementation of agroecological practices adapted to different contexts: as an example, CIS could be used to define the amount of mulch or the level of farm diversification according to the seasonal climate forecasts, the management and application of manure using ten-day forecast. The work also done by CCAFS to widespread these CIS using TICs could be a relevant contribution to on-going literature on agroecology that is barely exploring the use of TICs to support decision-making.

Conclusion

Agroecology promotes fundamental changes in the way we produce and consume food. Putting people at the center, it asks for fair economic conditions for all actors in the value chain and requires political governance that fosters the balance between ecological, economic and social components of food production. Agroecology promotes a system thinking approach to meet the complexity of climate change adaptation and mitigation within the food system. FAO's 10 elements of agroecology give a framework for understanding and operationalizing agroecology.

Although CCAFS activities were not designed following the principles of agroecology, on the ground many promoted practices were agroecological and several of the 10 FAO elements were addressed. Efficiency, recycling, co-creation and sharing of knowledge were the agroecological elements most addressed and explored in CCAFS activities. Resilience, diversity, human and social values or responsible governance were also included, but with a different perspective, focusing mostly on the agricultural production phase without considering the overall food system. The socio-economic resilience of existing farming systems through the exploration of synergies between on-farm and off-farm activities, the resilience of agroecosystems to pests and diseases are key gaps. Diversity was mostly considered at plot and farm scales without fully exploring diversity at the landscape scale or the diversification of economic activities. The principle of human and social values was mainly considered through the lens of gender inclusion and participatory and multi-stakeholder processes. It was also indirectly taken into account by the strong participatory approach of CCAFS. The work conducted by CCAFS, focusing mostly on the production side of the food system mostly considered levels one to three of Gliessman's five levels of transition towards sustainable food systems (2016).

To better align alignment CCAFS activities with agroecological principles a set of interventions are proposed to improve or reorient on-going activities. We recommended 5 main areas of intervention at policy level: a better integration of agroecological principles in the implementation of NDCs, system thinking for food system transformation, strengthening landscape-level activities, developing projects on circular and solidarity economy and using CIS to support the implementation of agroecological practices.

References

Alexandratos N, Bruinsma J. 2012. World agriculture towards 2030/2050: the 2012 revision. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (Available at: http://www.fao.org/3/a-ap106e.pdf)

Altieri MA. 1995 Agroecology: The Science of Sustainable Agriculture. Boulder, CO: Westview.

Altieri MA, Nicholls CI, Henao A, Lana MA. 2015. Agroecology and the design of climate change-resilient farming systems. *Agronomy for sustainable development*, 35(3):869-890.

Anderson CR, Bruil J, Chappell MJ, Kiss C, Pimbert MP. 2019. From transition to domains of transformation: Getting to sustainable and just food systems through agroecology. *Sustainability,* 11(19). (Available at: https://doi.org/10.3390/su11195272)

Antwi EK, Otsuki K, Osamu S, Obeng FK, Gyekye KA, Boakye-Danquah J, Boafo YA, Kusakari Y, Yiran GAB, Owusu AB, et al. 2014. Developing a community-based resilience assessment model with reference to Northern Ghana. *IDRiM Journal,* 4:73–92. (Available at: https://doi.org/10.5595/idrim.2014.0066)

Biovision. 2020. Agroecology Info Pool. Biovision Foundation for Ecological Development & International Panel of Experts on Sustainable Food Systems. (Available at: https://www.agroecology-pool.org/)

Biovision Foundation for Ecological Development & IPES-Food. 2020. Money Flows: What is holding back investment in agroecological research for Africa? Biovision Foundation for Ecological Development & International Panel of Experts on Sustainable Food Systems. (Available at https://www.agroecology-pool.org/moneyflowsreport/)

Cash D, Adger W, Berkes F, Garden P, Lebel L, Olsson P, Pritchard L, Young O. 2006. Scale and Cross-Scale Dynamics: Governance and Information in a Multilevel World. *Ecology and Society*, 11(2). (Available at: www.jstor.org/stable/26265993)

Darmaun M, Leippert F, Bernoux M, Mpheshea M. 2020. The potential of agroecology to build sustainable livelihoods and resilient food. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). In Press.

Duru M, Therond O, Martin G, Martin-Clouaire R, Magne MA, Justes E, Aubertot J-N, Savary S, Bergez J-E, Sarthou JP. 2015. How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agronomy for Sustainable Development*, 35(4), 1259-1281. (Available at: https://doi.org/10.1007/s13593-015-0306-1)

Duru M, Therond O, Fares M. 2015. Designing agroecological transitions: A review. *Agronomy for Sustainable Development*, 35:1237–1257. (Available at: https://doi.org/10.1007/s13593-015-0318-x)

Eriksen SH, Cramer LK, Vetrhus I, Thornton P. 2019. Can climate interventions open-up space for transformation? Examining the case of climate-smart agriculture (CSA) in Uganda. *Frontiers in Sustainable Food Systems*, 3:111.

FAO. 2013. Climate-smart agriculture sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (Available at: http://www.fao.org/climate-smart-agriculture-sourcebook/en/)

FAO. 2017. The FAO Strategy on Climate Change. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (Available at http://www.fao.org/3/a-i7175e.pdf)

FAO. 2018. The 10 elements of agroecology: Guiding the transition to sustainable food and agricultural systems. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (Available at: http://www.fao.org/3/i9037en/i9037en.pdf).

FAO. 2019 The Ten Elements of Agroecology, guiding the transition to sustainable food and agricultural systems. COAG 41st Session. (Available at: http://www.fao.org/3/na160en/na160en.pdf)

Geels FW. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31: 257–1274. (Available at: https://doi.org/10.1016/S0048-7333(02)00062-8)

Geels FW. 2005. Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological Forecasting and Social Change*, 72(6):681-696.

Gliessman SR. 2004. Agroecology and agroecosystems. *Agroecosystems analysis*, 43:19-29. (Available at https://www.tandfonline.com/doi/abs/10.1300/J064v22n03_10)

Gliessman SR. 2007. Agroecology: the ecology of sustainable food systems. NewYork, USA: CRC Press, Taylor & Francis.

Gliessman SR. 2016. Transforming food systems with agroecology. *Agroecology and Sustainable Food Systems*, 40(3):187–189. (Available at: https://doi.org/10.1080/21683565.2015.1130765)

Gumucio T, Twyman J, Clavijo M. 2017. Gendered Perspectives of Trees on Farms in Nicaragua: Considerations for Agroforestry, Coffee Cultivation, and Climate Change. Cali, Colombia: International Center for Tropical Agriculture (CIAT). (Available at: https://ccafs.cgiar.org/publications/gendered-perspectives-trees-farms-nicaragua-considerations-agroforestry-coffee#.WMa1xqLauUk)

Gumucio T, Alves MDA, Orentlicher N, Hernández Ceballos MC. 2018. Analysis of gender research on forest, tree and agroforestry value chains in Latin America. *Forests, Trees and Livelihoods,* 27**:**69-85.

Harvey CA, Chacón M, Donatti CI, Garen E, Hannah L, Andrade A, Bede L, Brown D, Calle A, Chará J, Clement C, et al. 2014. Climate-smart landscapes: opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conservation Letters,* 7:77–90. (Available at: https://doi.org/10.1111/conl.12066)

Havet A, Coquil X, Fiorelli JL, Gibond A, Martel G, Roche B, Ryschawy J, Schaller N, Dedieu B. 2014. Review of livestock farmer adaptations to increase forages in crop rotations in western France*. Agriculture Ecosystems and Environment*, 190:120–127. (Available at: http://dx.doi.org/10.1016/j.agee.2014.01.009)

Hill SB. 1998. Redesigning agroecosystems for environmental sustainability: a deep systems approach. *Systems Research*, 15:391–402.

HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. (Available at: http://www.fao.org/3/ca5602en/ca5602en.pdf)

Howlett M, Rayner J. 2007. Design principles for policy mixes: Cohesion and coherence in 'new governance arrangements.' *Policy and Society*, 26(4):1-18.

IPES-Food. 2016. From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food systems. (Available at http://www.ipes-food.org/_img/upload/files/UniformityToDiversity_FULL.pdf)

Jagustović R, Zougmoré RB, Kessler A, Ritsema CJ, Keesstra S, Reynolds M. 2019. Contribution of systems thinking and complex adaptive system attributes to sustainable food production: Example from a climate-smart village. *Agricultural Systems*, 171:65–75. (Available at: https://doi.org/10.1016/j.agsy.2018.12.008)

Le Coq JF, Sabourin E, Milhorance De Castro C, Howland F, Montouroy Y, Duron M, et al. 2019. Comparative dynamics of integration of climate change issue in policies for agricultural sector in Latin America and Caribe. CGIAR.

Mbow C, Rosenzweig C, Barioni LG, Benton TG, Herrero M, Krishnapillai M, Liwenga E, Pradhan P, Rivera-Ferre MG, Sapkota T, Tubiello FN, Xu Y. 2019. Food Security. In Shukla PR, Skea J, Calvo Buendia E, Masson-Delmotte V, Pörtner H-O, Roberts DC, Zhai P, Slade R, Connors S, van Diemen R, et al. eds. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. In press.

Mockshell J, Villarino M, Eliza, J. 2018. Agroecological intensification: potential and limitations to achieving food security and sustainability. *Reference Module in Food Science: Encyclopedia of Food Security and Sustainability,* 3:64-74. (Available at: https://doi.org/10.1016/B978-0-08-100596-5.22211-7)

Mugwanya N. 2019. Why agroecology is a dead end for Africa. Outlook on Agriculture, 48(2), 113-116. (Available at: https://doi.org/10.1177/0030727019854761)

Ouédraogo M, Partey ST, Zougmoré RB, Derigubah M, Sanogo D, Boureima M, Huyer S. 2018. *Mainstreaming gender and social differentiation into CCAFS research activities in West Africa: lessons learned and perspectives*. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). (Available at: https://ccafs.cgiar.org/publications/mainstreaming-gender-and-social-differentiation-ccafs-research-activities-west-africa#.XdhFgS0ZOu4)

Saj S, Torquebiau E, Hainzelin E, Pages J, Maraux F. 2017. The way forward: An agroecological perspective for Climate-Smart Agriculture. *Agriculture, Ecosystems & Environment*, 250:20-24. (Available at: https://doi.org/10.1016/j.agee.2017.09.003)

Scherr SJ, Shames S, Friedman R. 2012. From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security,* 1(12). (Available at: http://doi.org/10.1186/2048-7010-1-12)

Sinclair F, Wezel A, Mbow C, Chomba S, Robiglio V, Harrison R. 2019. The Contribution of Agroecological Approaches to Realizing Climate-Resilient Agriculture. Rotterdam and Washington, DC. (Available at: www.gca.org.)

St-Louis M, Schlickenrieder J, Bernoux M.2018. The Koronivia Joint Work on agriculture and the convention bodies: an overview. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). (Available at: http://www.fao.org/3/ca1544en/CA1544EN.pdf)

Richards M, Bruun TB, Campbell B, Gregersen LE, Huyer S, Kuntze V, Madsen STN, Oldvig MB, Vasileiou I. 2016. How countries plan to address agricultural adaptation and mitigation: An analysis of Intended Nationally Determined Contributions. CCAFS dataset version 1.2. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Zougmoré RB, Partey ST, Totin E, Ouédraogo M, Thornton P, Karbo N, Sogoba B, Dieye B, Campbell BM. 2019. Science-policy interfaces for sustainable climate-smart agriculture uptake: lessons learnt from national science-policy dialogue platforms in West Africa. *International Journal of Agricultural Sustainability*, 17(5):367–382. (Available at: https://doi.org/10.1080/14735903.2019.1670934)

Waters-Bayer A, Kristjanson P, Wettasinha C, van Veldhuizen L, Quiroga G, Swaans K, Douthwaite B. 2015. Exploring the impact of farmer-led research supported by civil

society organisations. *Agriculture & Food Security*, 4:1–7. (Available at: https://doi.org/10.1186/s40066-015-0023-7)

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. (Available at: https://doi.org/10.1051/agro/2009004)

Wezel A, Silva E. 2017. Agroecology and agroecological cropping practices. Agroecological practices for sustainable agriculture: principles, applications, and making the transition. London: World Scientific, 19-50. (Available at: https://doi.org/10.1142/9781786343062_0002)

Wise TA. 2019. Opinion in sustainable agriculture: Agroecology as Innovation. Baltimore, Maryland, USA: Food Tank: The think tank for food. (Available at: https://foodtank.com/news/2019/07/opinion-agroecology-as-innovation)

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