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THE POTENTIAL OF AGROECOLOGY TO BUILD CLIMATE-RESILIENT LIVELIHOODS AND FOOD SYSTEMS

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FOREWORD

Sustainability and resilience of food systems are a matter of survival, for those who earn their living in food production and value chains, but also for humanity as a whole. The COVID-19 crisis impressively demonstrated how vulnerable our current food systems are to disruptions. Climate change, though on a longer time-scale, poses an even bigger and deeper challenge for our food systems.

Agroecology could be one of the most promising approaches to achieve the mitigation and adaptation potentials of agricultural systems to climate change and to strengthen their resilience. Yet, we still lack thorough and robust comparative assessments supporting this claim, as well as guiding steps to enable the transformation of international and national policies.

The study at hand, mobilizing international and national level assessments and scientific methodologies provides solid evidence that biodiverse agroecological systems built on local communities increase resilience to climate change. Agroecology is not a silver bullet, but it provides urgently needed impulses and principles to transform food systems in line with the sustainable development goals.

The study also identifies barriers to an agroecological transformation. It shows that overcoming silo-thinking, embracing complexity and investing in agroecological, integrated research and access to knowledge through functioning extension services are much needed. Policies need to provide an enabling environment and a level playing ground for enhancing the adoption of agroecological principles. Evidence-based policy setting is therefore the need of the hour.

We welcome this work done through a strong multistakeholder and multi-level collaboration, engaging scientists, farmers, governments and civil society organizations to broaden the knowledge base on the agriculture-climate nexus. Enriched and peer-reviewed by external experts' inputs, its results feed into parallel policy processes, such as the Koronivia Joint Work on Agriculture (KJWA), the CFS and the COP, bridging the gap between science and decision-making processes.

We thank the Swiss Agency for Development and Cooperation (SDC) for supporting this timely and important piece of work.

Frank Eyhorn
CEO, Biovision Foundation

René Castro
Food and Agriculture Organization (FAO)

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"Transformation will only happen through an articulation between innovation at the local level, national policies and the way we think at the global level."
Patrick Caron, Chair of the High-Level Panel of Experts/HLPE on Food Security and Nutrition, conclusion of the presentation of the HLPE report on agroecology, CFS 46, October 2019.

"We cannot solve our problems with the same thinking we used when we created them."
Albert Einstein

In light of these quotes, this study was conducted and written by Maryline Darmaun (FAO), Fabio Leippert (Biovision), Martial Bernoux (FAO) and Molefi Mpheshea (FAO). Lead Chapter authors were Adrian Müller (FIBL), Matthias Geck (Biovision), Martin Herren (Biovision), Wambui Irungu (consultant), Mary Nyasimi (consultant), Jean Michel Sene (Enda Pronat), Mamadou Sow (Enda Pronat), Moussa Ndienor (ISRA), Ibrahima Sylla (consultant) and Céline Termote (Bioversity International Kenya). Significant support was provided by Mohamed Diagne (FAO), Martin Lichtenegger (Biovision), Maike Nesper (Biovision), Makhfousse Sarr (FAOSN), Aissatou Sylla (FAOSN), Gregory Zimmermann (Biovision). Significant support in data collection in Senegal was provided by Ibrahima Sall (consultant), Daro Samb (consultant), Soulèye Ndiaye (consultant), Mansour Thiongane (consultant).

The rich multistakeholder, mutli-level and interdisciplinary collaboration developed throughout this work illustrates the nature and strength of agroecology in the spirit of the authors.

- At the country level, this study brought together colleagues from two FAO country offices, the Senegal and Kenya offices, from local NGOs (Enda Pronat, Institute for Culture and Ecology (ICE) and Bioversity International Kenya) and involved farmers from both countries.
- At the global level, a tight very first collaboration between FAO, Biovision and FIBL made this work possible, closely followed and supported by a cross-divisional spirit between CBC, AGP and AGA within headquarters in Rome, in particular Abram Bicksler (AGPM), Emma Siliprandi (AGP), Jimena Gomez (AGPM) and Anne Mottet (AGAG).

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This very first work (within FAO) bringing together two much needed topics for the future of food systems, climate change and agroecology, has been made possible thanks to the financial contribution of the Swiss Agency for Development and Cooperation (SDC). We wish to thank the SDC for their trust and for supporting this very first and inspiring collaboration.

Any omissions of contributors to this guide are unintentional.

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ACRONYMS AND ABBREVIATIONS

ACT	Agroecology Criteria Tool
AEZ	Agroecological zones
AGA	Animal Production and Health Division of FAO
AGN	African Group of Negotiators
AGP	Plant Production and Protection Division of FAO
ALV	African Leafy Vegetables
AMS	Associations of Mayors of Senegal
ASRGM	Agence Sénégalaise de la reforestation et de la grande muraille verte
ASDS	Agricultural Sector Development Strategy
ANACIM	Agence Nationale de l'Aviation Civile et de la Météorologie
BAME	Bureau d'analyses macro-économiques
CAN	Climate Action Network
CBC	Climate and Environment Division of FAO
CBD	Convention on Biological Diversity
CBO	Community-based organization
CCASA	Changements Climatiques et Agriculture Sénégalaise
CDH	Center for the Development of Horticulture
CDM	Clean Development Mechanism
CESE	Social and Environmental Economic Council
CFS	Committee on World Food Security
CIRAD	French Agricultural Research Centre for International Development
COMNACC	Comité National sur les Changements Climatiques
CNCR	Conseil national de concertation et de coopération des ruraux
COP	Conference of the Parties
CSA	Climate-smart agriculture
CSE	Centre de Suivi Écologique
CSO	Civil society organization
CT	Collectivités Territoriales
DEEC	Direction de l'Environnement et des Etablissements Classés

DyTAES	Dynamique sur la Transition Agroécologique au Sénégal
ENDA PRONAT	Association pour l'Environnement et Developpement Action pour une Protection Naturelle des Terroirs
ESEC	Economic, Social and Environmental Council
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FENAB	Fédération Nationale pour l'Agriculture Biologique
FFS	Farmer field school
FIBL	Research Institute of Organic Agriculture
FGD	Focus group discussion
FSN	Food security and nutrition
GCA	Global Commission on Adaptation
GGGI	Global Green Growth Institute
GKP	Global Knowledge Products
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HDI	Human Development Index
HLPE	High-Level Panel of Experts
INP	Institut National de Pédologie
IP	Innovation Platform
ICE	Institute for Culture and Ecology
IFOAM	International Federation of Organic Agriculture Movements
INGOs	International non-governmental organizations
IPCC	Intergovernmental Panel on Climate Change
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPES-Food	International Panel of Experts on Sustainable Food Systems
ISRA	Institut Sénégalais de Recherches Agricoles
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
KCSAIF	Kenya Climate-Smart Agriculture Implementation
KCSAS	Kenya Climate-Smart Agriculture Strategy
KJWA	Koronivia Joint Work on Agriculture
LDC	Least developed country
LOASP	Agro-Sylvo-Pastoral Orientation Law
LPSEED	Environment and Sustainable Development Sector Policy Letter
LPSDA	Agriculture Sector Development Policy Letter
MAER	Ministry of Agriculture and Rural Development

MEDD	Ministry of the Environment and Sustainable Development
MOALF	Ministry of Agriculture, Livestock and Fisheries
NCCRS	National Climate Change Response Strategy
NCCAP	National Climate Change Action Plan
NDC	Nationally determined contribution
NGO	Non-governmental organization
NNGO	National non-governmental organizations
NSIF/SLM	National Strategic Investment Framework for Sustainable Land Management
PANA	Plan d'action national pour l'adaptation
PD	Policy Directorate
PNIASAN	Programme National d'Investissement Agricole pour la Sécurité Alimentaire et la Nutrition
PRACAS	Programme d'Accélération de la Cadence de l'Agriculture Sénégalaise
PSE	Plan Sénégal Emergent
SB	Subsidiary body
SBI	Subsidiary Body for Implementation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDG	Sustainable food system
SFS	Clean Development Mechanism
SHARP	Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists
SINGI	Sustainable Income Generating Investment Group
SLM	Sustainable land management
SNDD	National Strategy for Sustainable Development
SNFAR	National Strategy for Agricultural and Rural Training
SSA	Sub-Saharan Africa
SRI	System of Rice Intensification
TAPE	Tool for Agroecology Performance Evaluation
UCAD	Cheikh Anta Diop University
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Climate change has severe negative impacts on livelihoods and food systems worldwide. Our future climate according to latest scenarios seriously undermine current efforts to improve the state of food security and nutrition, especially in sub-Sahara Africa. To address this to its full extent, there is an urgent need for transformational change of our food systems towards more sustainability and resilience. Agroecology could play a vital role here. As a response to FAO's governing bodies' call for increased evidence-based work on agroecology, this study aims to elaborate on existing links between agroecology and climate change. It provides evidence on the technical and policy potential of agroecology to build resilient food systems. Inspired by the idea that transformation will only happen through a coordinated approach among all levels, this study was jointly developed by a broad set of actors from UN agencies (FAO), research institutes (FIBL, Bioversity, ISRA) and CSOs (Biovision, Enda Pronat, ICE) and thus combines evidence from a broad range of backgrounds and perspectives.

The overall research question of this study was:
How can agroecology foster climate change adaptation, mitigation and resilience through practices and policies?

To provide a robust and evidence based answer to this we analysed three different dimensions:

1. International policy arena, in particular in the United Nations Framework Convention on Climate Change and the Koronivia Joint Work on Agriculture;
2. Peer-reviewed scientific studies on agroecology applying a meta-analysis; and
3. Two case studies in Kenya and Senegal that assess both, the policy potential of agroecology in respective national settings and the technical potential of agroecology to foster climate resilience on farm-level.

The main findings of the study are:

- Robust scientific evidence demonstrates that agroecology increases climate resilience. Success factors for this are that agroecology builds on:
  a) ecological principles, in particular on biodiversity, overall diversity and healthy soils (*meta-analysis and case studies results*);
  b) social aspects, in particular on the co-creation and sharing of knowledge and fostering traditions (*case study results*).
- More than ten percent of the nationally determined contributions (NDCs) by UNFCCC member states mention agroecology and consider it a valid approach to address climate change. The climate potential of agroecology is furthermore backed by the *IPCC Special Report on Climate Change and Land* and the *2019 HLPE report* of the Committee on World Food Security (CFS) (*int. policy analysis result*).
- The interdisciplinary and systemic nature of agroecology is key for its true transformational power. However these characteristics are also the main challenges for both, conducting comprehensive research and policy revisions: typically research concepts and policy processes focus on the productive dimension with selective sectorial views *(meta-analysis and policy analysis results)*.

The key recommendations from this study are:

- Given the sound knowledge base, fostering agroecology to build resilience should be recognized as a viable climate change adaptation strategy.
- Barriers to the scaling-up of agroecology need to be addressed: amongst others, improved access to knowledge and understanding of systemic approaches should be fostered across sectors, stakeholders and scales.
- Further comparative research on the multidimensional effects of agroecology is needed.
- Agroecology's transformative resilience-building potential depends on its holistic and systemic nature which goes beyond a set of practices and includes: a social movement for producers' empowerment and a multidisciplinary scientific paradigm.

CHAPTER 1

CHAPTER

1

INTRODUCTION

1.1 RATIONALE: BRINGING AGROECOLOGY INTO CLIMATE CHANGE DISCUSSIONS

Climate change has severe negative impacts on livelihoods and food systems worldwide, with future projections, seriously undermining current efforts to improve the state of food security and nutrition, especially in sub-Sahara Africa (SSA) (Strohmaier *et al.*, 2016). The 2018 report on the State of Food Insecurity raised an urgent appeal to accelerate and scale-up actions to strengthen resilience and enhance adaptive capacity in agricultural sectors.

There is an urgent need for a transformational change of our food systems towards more sustainability and resilience. This was recently highlighted by the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C and the Special Report on Climate Change and Land (IPCC, 2018; IPCC, 2019), as well as by the State of the World's Biodiversity for Food and Agriculture report (FAO, 2019a) and various other recent key publications on issues related to climate change.

At the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, the Paris Agreement recognized "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change". As a response two years later, at COP 23 in Bonn, the international community adopted a decision to have a workstream on agriculture through the Koronivia Joint Work on Agriculture (KJWA). Through their potential for adaptation, mitigation and building resilience ecological and sustainable agriculture and respective food systems are a fundamental part of the solution to tackle climate change. These approaches are uniquely placed to help countries deliver on climate goals and the 2030 Agenda for Sustainable Development.

The entry-point and focus of this study is climate change. Indeed, although both agroecology and climate change have complex and beneficial relationships, this fact is often insufficiently disseminated to and acknowledged by a broad audience. Thus hindering agroecology to be seen as an effective path to follow in order to set-up national climate targets (Côte *et al.*, 2019).

Since the very first international symposium on agroecology organized by the Food and Agriculture Organization of the United Nations (FAO) in 2014, followed by regional conferences and a second international symposium on agroecology in 2018, agroecology is better represented on the global agenda. In fact, at the 26th Session of the Committee on Agriculture and at the 40th Session of the FAO Conference in 2017, FAO's governing bodies highlighted the importance of agroecology for a transition to sustainable food and agriculture. They further called for the need to strengthen normative and evidence-based work, as well as to foster research to the end of increasing the collection of evidence and qualitative data on agroecology.

The launch of a global initiative[1] on scaling up agroecological production systems in support of the Sustainable Development Goals (SDGs) in 2018 (FAO, 2018a), and the CFS HLPE (2019) report on "Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition", are two additional affirmations that further illustrate the multi-level momentum of agroecology: from the field to the regional, national and international levels.

Agroecology has an important role to play in transforming agriculture and food systems. Indeed, several sets of data, results, evidence and experiences exist from the field and from various countries. They are generally observed by farmers, CSOs, research institutions and supported by those governments that uphold agroecology. Such evidence resulted into a wide number of reports that present agroecology as a promising systemic approach to address climate change by unlocking adaptation and mitigation potentials in agriculture and food systems, that would ultimately build resilience and stimulate sustainable development (for an overview see e.g. Baker, *et al.*, 2019).

Despite this increased visibility in public debates and the presumably good performance of agroecology to transform agriculture towards increased sustainability, it has not been widely adopted by farmers yet. This is traced back to various reasons, such as the lack of enabling institutional and policy environments, the strong pressure from ongoing industrialization and commercialization processes or the lack of funds for research and education (Nicholls and Altieri, 2018).

Agroecology existed long before climate change was seen as a major threat for the agriculture sectors, therefore it is not an approach specifically designed to address climate change. Thus, its climate resilience qualities which are examined in this study are rather an outcome of its systemic approach and underlying nature, mimicking natural, complex ecosystems. However, there is still insufficient comprehensive and structured evidence supporting the claim of its climate change adaptation potential. Furthermore there is little information available on the broader political and political-economic challenges and constraints that need to be addressed when building on the agroecology approach to hedge against climate change. Unlike food-system-focused fora, such as the 46th Session of the CFS (CFS 46) with the endorsement of the HLPE report (HLPE, 2019), which are increasingly highlighting the essential role of agroecology in food systems transformations, it does not yet get the same recognition and visibility in climate change discussions.

Just recently, Sinclair *et al.* (2019) published a background report on "the contribution of agroecological approaches to realizing climate-resilient agriculture" for the Global Commission on Adaptation (GCA), which includes recommendations on the use of agroecological practices to build resilience of smallholder farms, and a commitment on the action track of agriculture and food security to enable access to agroecological practices for 60 million smallholders. It proposes adaptation and mitigation benefits derived from 13 agroecological principles identified by HLPE (2019), which occur at four scales: (1) field scale; (2) farm (or livelihood) scale; (3) landscape (or community) scale; and (4) food system scale.

The transformation of agriculture and food systems to address the challenges of a changing climate will only transpire through collaboration of various actors of the food system which can build on their technical and policy-related experience. Following this logic, the study on "The potential of agroecology to build sustainable livelihoods and resilient food systems" is designed as a multi-stakeholder collaboration between the Food and Agriculture Organization of the United Nations (FAO), research institutions such as

[1] The Scaling-up Agroecology Initiative: http://www.fao.org/3/I9049EN/i9049en.pdf

the Research Institute of Organic Agriculture (FIBL), the *Institut Sénégalais de Recherches Agricoles* (ISRA) and *Bioversity International Kenya*, together with civil society organizations (CSOs) including Biovision - Foundation for Ecological Development, the *Association pour l'Environnement et Developpement Action pour une Protection Naturelle des Terroirs* (Enda Pronat) and the Institute for Culture and Ecology (ICE).

1.2 OVERALL OBJECTIVE AND SET-UP

As a response to FAO's governing bodies' call for increased evidence-based work on agroecology, this study aims to highlight the links between agroecology and climate change, by providing evidence on the technical (i.e. ecological and socio-economic) and policy potential of agroecology to build resilient food systems.

This report has the objective to provide evidence that answers the following question:

How can agroecology foster climate change adaptation, mitigation and resilience through practices and policies?

Inspired by the idea that transformation will only happen through a coordinated approach among all levels, this study aims to combine evidence from a broad range of backgrounds and perspectives. Considering the local level of action and implementation, the national level defining the governance framework and the policies, and the international agenda at the global level, this study combines different dimensions of analysis:

1. At the international level we conducted:
- **A technical potential analysis** which provides scientific evidence from peer-reviewed articles on the performance of agroecology to build climate resilience (meta-analysis).
- **A policy potential analysis** which assesses the potential for agroecology to be considered and recommended as a relevant adaptation/mitigation approach in the agriculture-climate discussions.

2. At the national level, we conducted **two country case studies in Senegal and Kenya**, both consisting of:
- **A technical potential analysis** which provides a better understanding of the ecologic and socio-economic performance of agroecology. Based on a rigorous comparative analysis we answer the question whether agroecological agroecosystems are more resilient to climate change than non-agroecological systems, and if so why.
- **A policy potential analysis** which provides a better understanding of the current political context, as well as the enabling environment and the obstacles for agroecology to be considered in the decision- and policy-making process.

FIGURE 1.

THE MULTILEVEL ANALYSIS APPROACH

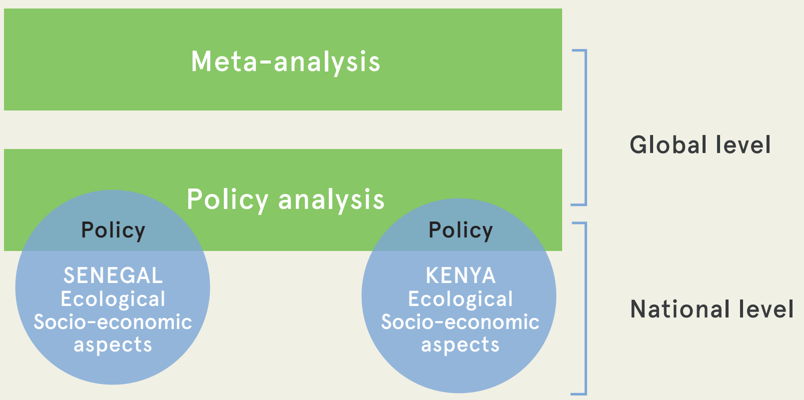


Illustration of the two levels (international and national) of analysis and the four components: the meta-analysis of research papers, analysis of the policy potential at the international level, analysis of the policy potential at the national level, and analysis of the technical potential at the national/local level.

The results of this study are fed back to UNFCCC- and national climate-related discussions. While compiling this study, already selected submissions were made on topics 2b, 2c, and 2d of the Koronivia process (see **Chapter 2.2**) that build on the insights from this work.

1.3 DEFINITIONS AND CONCEPTS

1.3.1 Agroecology framework: how to understand agroecology in this study

Territoriality, context-specifity and a bottom-up approach are at the heart of agroecology. No single universal definition exists for it. Indeed, recent years have seen the multiplication of definitions of agroecology, nuances depending on the authors, institutions or CSOs, all highlighting its dynamic concept (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 and Silva, 2017; Agroecology Europe, 2017).

Suggested by the IPCC as one of the options of sustainable land management (SLM), including agroforestry (IPCC, 2019), agroecology is the application of ecological sciences to the study, design and management of agriculture (Altieri, 1995). Its core elements are integrated land-use systems that maintain species diversity, agrobiodiversity, the improvement of ecological processes and delivery of ecosystem service, the strengthening of local communities and recognition of the role and value of indigenous and local knowledge (IPCC, 2019).

The HLPE report defines agroecological approaches to sustainable food systems for food security and nutrition as follows:

> **Agroecological approaches favour the use of natural processes, limit the use of synthetic 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 (FSN) (HLPE, 2019, p. 39).**

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

Bridging ecological and social dimensions, people-centred, knowledge-intensive and rooted in sustainability, agroecological approaches aim at transforming food and agriculture systems, addressing the root causes of problems and providing holistic and long-term solutions, as expected by the 2030 Agenda (FAO, 2018 a). Agroecology particularly contributes to no poverty (SDG 1), zero hunger (SDG 2), good health and wellbeing (SDG 3), decent work and economic growth (SDG 8), responsible consumption and production (SDG 12), climate action (SDG 13) and life on land (SDG 15) (CNS-FAO, 2019). Also, the core principles on which agroecological practices build (i.e.: diversity, efficient use of natural resources, nutrient recycling, natural regulation and synergies) characterize their inherent adaptation and resilience potential to climate change (Côte *et al.*, 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 so as to characterize inherent properties of agroecology and to ensure a common understanding.

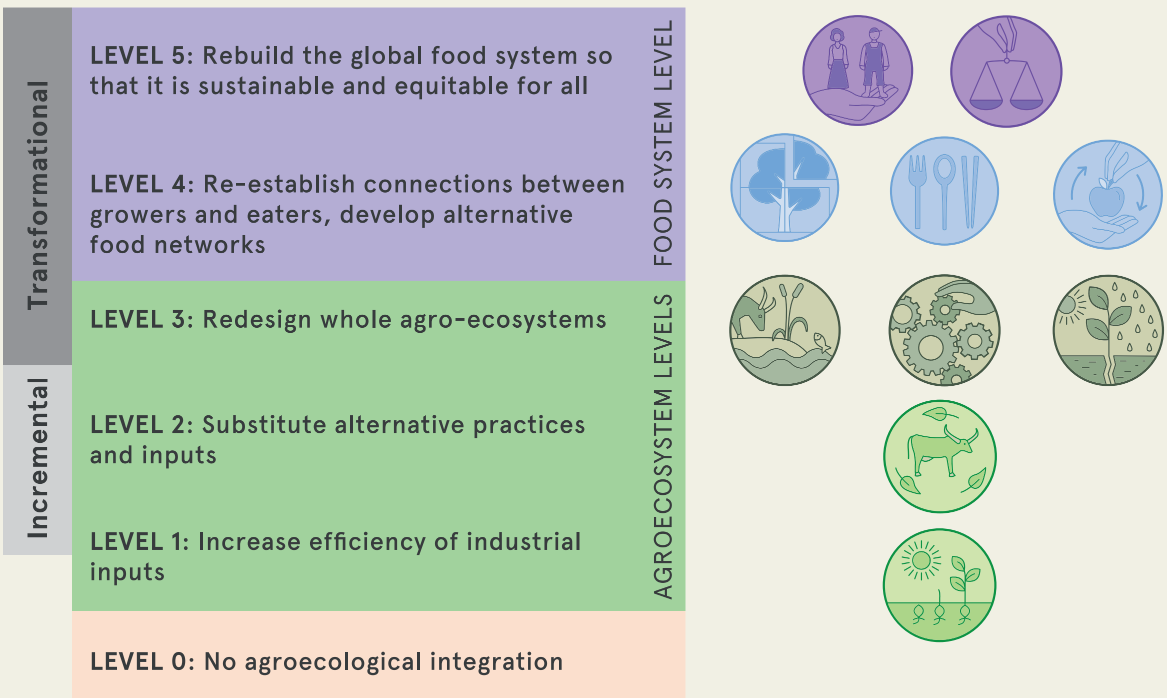
Stemming from FAO regional seminars[2] and seen as an analytical tool, the FAO ten elements of agroecology aim to help countries to operationalize agroecology. They provide an overall framing of important properties or principles of agroecological systems and approaches, as well as key considerations in developing an enabling environment for agroecology. In particular:

- 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 sharing of knowledge**;
- two focus on context features: **human and social values; culture and food traditions; and**
- two refer to the enabling environment: **responsible governance; circular and solidarity economy** (FAO, 2018b).

As illustrated below, these ten elements are encompassing different scales (agroecosystem and food system) and different levels of transitions towards sustainable food systems (SFSs) (as defined by Gliessman, 2014). While the transition at levels one and two is incremental, at levels three to five it is transformational.

FIGURE 2.

THE FAO 10 ELEMENTS OF AGROECOLOGY AND GLIESSMAN'S (2014) LEVELS OF TRANSITION TOWARDS SUSTAINABLE FOOD SYSTEMS



Source: Biovision (n.d.), inspired by HLPE (2019).

This study uses these ten elements of agroecology as its analytical framework, which looks at agriculture through a food system approach (encompassing the food value chain).

[2] The Ten Elements of Agroecology were developed through a synthesis process. They are based on the seminal scientific literature on agroecology – in particular, Altieri's (1995) five principles of agroecology and Gliessman's (2014) five levels of agroecological transitions. This scientific foundation was complemented by discussions held in workshop settings during FAO's multi-actor regional meetings on agroecology from 2015 to 2017, which incorporated civil society values on agroecology, and subsequently, several rounds of revision by international and FAO experts.

1.3.2 Climate resilience

Climate change is expected to affect agriculture and food security in various ways and the effects will be sector- and region-specific with arid areas being the most affected. Taking crop production in Africa as an example, climate change will result in yield reductions in most types of cereal grains, but with some regional differences. The Southern Africa region is expected to experience an 18 percent decline in maize yield, while the reduction for sub-Saharan Africa as a whole will be 22 percent (Lobell *et al.*, 2008).

With regard to livestock, there is a risk of loss due to expected prolonged droughts and rangeland degradation especially in northern and southern Africa which are expected to become drier as a result of increased surface temperatures and reduced precipitation (Masike and Urich, 2009). Crop production is mainly rain fed and livestock systems are often unsheltered or unprotected, making these production systems highly sensitive. These, together with high intra-and inter-seasonal climate variability, high frequency of droughts and floods, make African agriculture the most vulnerable (IPCC, 2014a). For this reason, there is a need to reduce this vulnerability, to adapt agricultural systems to climate change and to enhance their resilience.

Vulnerability is the degree to which a system could adversely be affected by shocks and stresses (climatic change and variability) depending on its adaptive capacity (IPCC, 2012). The potential impact of climate change upon a system is determined by its level of exposure and sensitivity. A system's level of exposure, in turn, is determined by climate drivers and risks and depends on the character, magnitude and timing of climate change and variation; while the level of sensitivity determines the extent to which a system could be affected by a given climate change exposure (Fritzche *et al.*, 2014). Thus, the resulting impact (risk) would be the function of threat to the system, to its vulnerability and it would be depending on its adaptive capacity (Alteri *et al.*,2015). Adaptive capacity consists of two dimensions: recovery from shocks and response to change. If the system experiences a shock and it fails to recover, it shows that it is vulnerable, but if it can moderate the risk, its ability to respond to change is manifested and, thus, it is resilient (**Figure 3**) (Gitz and Meybeck, 2012).

Resilience, on the contrary, is defined as the ability of a system to absorb the shock, maintain its function during the shock or the capacity to return to its functional state prior to the shock (IPCC, 2012). According to Gitz and Meybeck (2012), the concept of resilience is not limited to shock absorption or the capability to return to the previous state, but it rather emphasises a consistent aptitude towards adapting and learning to cope with changes and uncertainties. To achieve this, systems – including agriculture – will need a certain degree of capacities, such as: absorptive capacity, which is the ability to cope with and absorb effects of shocks and stress; adaptive capacity – the ability of systems, including its components, to adjust and adapt to shocks and stresses while functioning in accordance with the objective of the system; and transformative capacity which is the ability to drastically change in order to assume the new function.

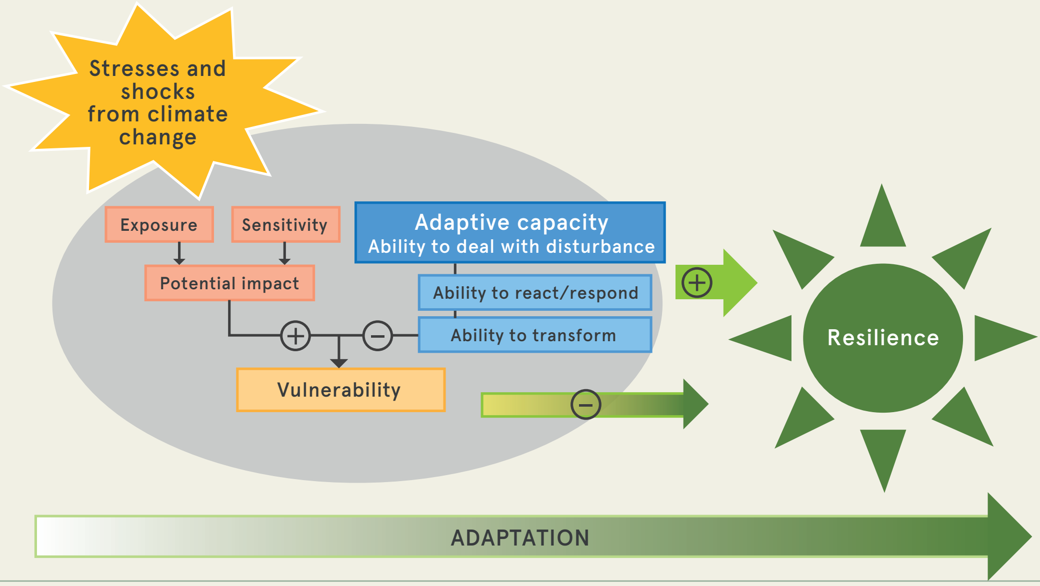
Through this lens, resilience is understood to directly constitute adaptation to climate change, since the more adaptive a system is, the more resilient it is (or vice and versa). Climate change adaptation is the adjustment of processes, practices and structures aimed at moderating potential risks from climate change (IPCC, 2014 a). Within agricultural systems, adaptation implies adjusting biophysical (ecological) and socioeconomic (including institutional) processes in an attempt to respond and/or prepare for the impacts of expected climate change and variability (FAO, 2017).

According to Altieri *et al.* (2015), vulnerability of agricultural systems could be reduced by increasing response capacity (a component of adaptive capacity), which is embedded within agroecological characteristics of the farm, and by the adoption of adaptation strategies that can moderate risks. Possible adaptation actions vary and depend on the context. In the context of resource constrained farmers such as in Africa, integrated agricultural systems could be crucial for adaptation (Gil *et al.*, 2017). These are inclusive of diversified systems, mixed systems, agroforestry and collectively regarded as agroecological. In most cases, these systems are considered as more resilient than those that are specialized with a single product. In Kenya, Ndiso *et al.* (2017) found cowpea-maize intercropping to result in higher soil moisture content than single maize; while in Mexico, the use of agroforestry in coffee production was able to maintain high levels of soil moisture compared to a single crop (Lin, 2007). In both cases, the use of these integrated systems resulted in higher yields. Furthermore, in a survey conducted after Hurricane Mitch in Central America, it was found that farmers who were practising diversification experienced less damage and economic loss in their farms than their specialized neighbouring farms (Holt-Giménez, 2002)

The value of integrated and diversified agricultural activities within the farming systems, in particular also the role of agroecology and diversity in reducing vulnerability against climate variability and extreme weather events, is recognized in the IPCC Special Report on Climate Change and Land (IPCC, 2019). According to this report, the diversification of different aspects of food systems is a crucial element for enhancing performance and efficiency that could manifest into increased resilience, reduced risks and maintained stability of food production in the wake of shocks and stresses. Since agroecology promotes diversification and synergistic relationship between farm components, whilst linking all elements of food systems, already Miles *et al.* (2017) suggested that the adoption of agroecological approaches could be an entry point for enhancing resilience for future climatic shocks, while at the same time providing a buffer against current shocks, such as droughts and floods.

FIGURE 3.

VULNERABILITY, ADAPTATION AND RESILIENCE FRAMEWORK



Resilience framework depicting a generic adaptation process and how the elements of adaptation interact to achieve resilience (adapted from FAO (2017), DFID Disaster Resilience Framework (2011), TANGO Livelihoods Framework (2007), DFID Sustainable Livelihoods Framework (1999), Fraser et al., (2011)). Building stronger resilience to climate change and resilient livelihoods requires increasing adaptive capacity and reducing the vulnerability of agroecological systems and livelihoods. These components of resilience may at the same time provide mitigation co-benefits.

Measuring resilience

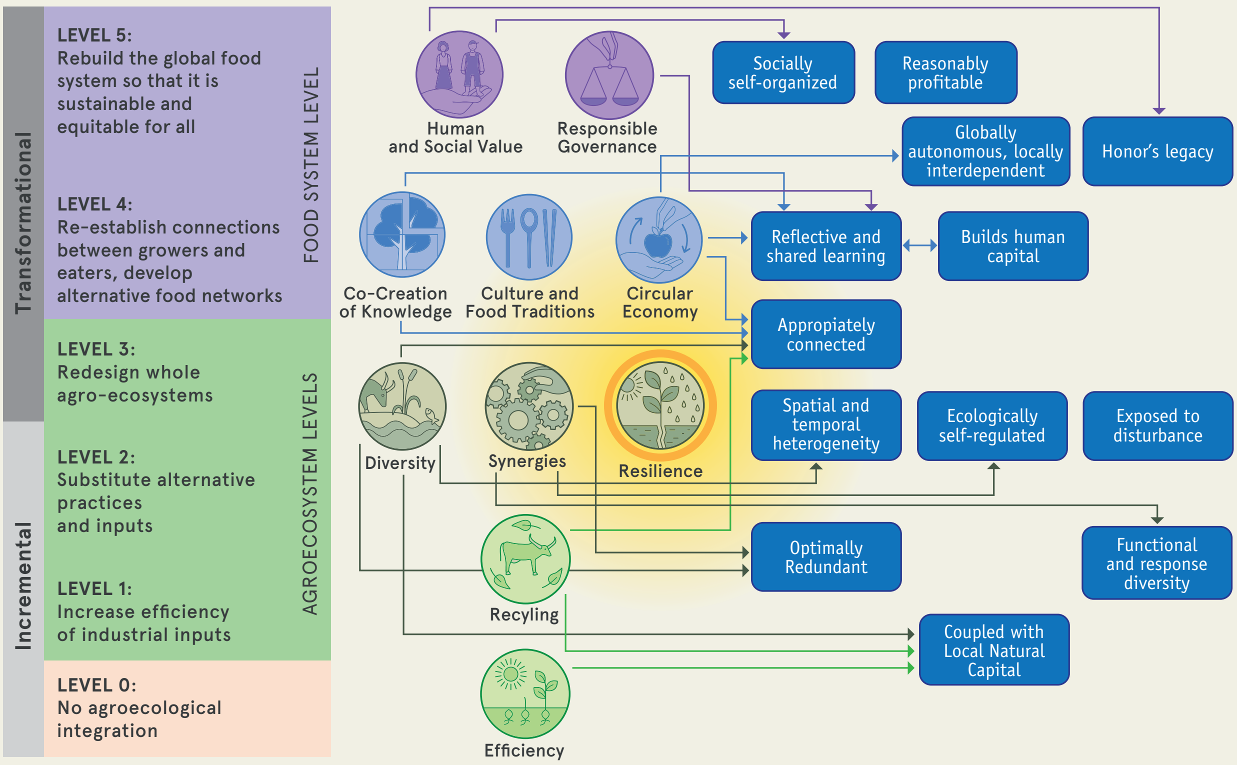
Due to its abstract and multifaceted nature, resilience is a challenging concept to measure (Cumming *et al.*, 2005). Claims that some approaches could enhance a system's resilience better than others are mostly based on variables like yield. This often happens when assessing a system's response to risks like drought or floods since one system is likely to perform better than the other during such events. However, for agroecosystems that are classified as both ecological and social, assessing their resilience based on outputs such as yield is not sufficient. There needs to be an identification of some proxies which are reflective of the intertwined nature of ecological and socio-economic components of agroecosystems. These proxies or indicators should be able to provide an indication of the level of resilience achieved within a system (Cabell and Oelofse, 2012). General rules and principles related to these proxies could then be identified and would be a guide towards translating them into actions in an attempt to increase resilience (Carpenter *et al.*, 2001).

According to Cabell and Oelofse (2012), such rules and principles can be grouped and divided into diferent indicators. Their presence in an agroecosystem may indicate that the system is resilient and that it possesses the capacity to adapt. These indicators need to be consistent with the agroecosystems characteristics which include both physico-chemical (ecological), and socio-economic (social and economic) aspects. The aim of assessing resilience should, therefore, be to understand the drivers of vulnerability in order to identify some intervention options that can improve climate resilience of agroecosystems.

In this study, in order to assess the resilience of agroecological systems, we adopt the resilience indicators as suggested by Cabell and Oelofse (2012). In addition, we used the ten elements of agroecology (FAO, 2018b), as a defining framework for agroecology, which puts more emphasis on the connectedness of the social and ecological nature of agroecosystems. We looked at how these different elements (or rather the principles contained therein) contribute to the resilience of agroecological systems. These indicators could be broadly grouped under the elements of sustainability which are, human, natural, social, financial and physical capital. These are the capitals of sustainable livelihoods. The proposed resilience indicators were then integrated into the SHARP tool (Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralist). With this tool we assess which livelihood capitals of agroecological systems contribute to building their resilience. This overall conceptualization of the study is illustrated in **Figure 4** below.

FIGURE 4.

LINKING FAO'S 10 ELEMENTS OF AGROECOLOGY AND GLIESSMAN'S FIVE LEVELS OF FOOD SYSTEM TRANSFORMATION (INSPIRED BY HLPE REPORT) WITH THE 13 SHARP RESILIENCE INDICATORS



CHAPTER 2

CHAPTER

2

INTERNATIONAL POLICY POTENTIAL

2.1 APPROACH

In this section, we present how agriculture developed as a topic in the international climate change policy debate and what role agroecology plays in current climate policies. A systematic literature research on policy reviews and reports was conducted to line out the historic developments (**Section 2.2.1**).

To capture the role of agroecology in international climate change policies, a mixed-methods approach was applied. In the quantitative analysis, NDCs of 136 countries (**Section 2.2.2**) and all the submissions (as well as the official workshop reports) on topics 2(a), 2(b), 2(c), and 2(d) related to KJWA (**Section 2.3**) were individually and systematically analysed, from an agroecological perspective. The conceptual framework for this analysis builds on FAO´s ten elements of agroecology (FAO, 2018b). In order to determine whether or not a specific point raised in any of the submissions can be considered to be addressing one of these ten elements, the indicators of Biovision´s Agroecology Criteria Tool (ACT) were applied (Biovision, n.d.).

These quantitative results are complemented by a qualitative analysis of 15 semi-structured interviews led with selected individuals (**Annex 1**) from key positions in governmental, multilateral, civil society, research and farmers' organizations. The objective of the interviews was to gain an in-depth understanding of stakeholders' opinions on and perceptions of the role of agroecology in the international climate change policy debate, particularly within the UNFCCC processes (including the KJWA). **Section 2.3.5** addresses stakeholders' perceptions on the current dynamics and critical points of the debate in the UNFCCC processes in general and specifically regarding the KJWA. The subsequent **Section 2.4** brings forward opinions regarding the future outlook on the links between agroecology and other sustainable agriculture approaches, and climate change.

2.2 BACKGROUND ON AGROECOLOGY IN THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) NEGOTIATIONS

2.2.1 The long road to Koronivia

The intrinsic connection between agriculture and climate change was already explicitly recognized at the first World Climate Conference in 1979, both in terms of "human activities that affect climate" and in terms of impacts of climate change on agriculture and food security (WMO, 1979). Climate change was "firmly put on the agenda of politicians" (Gupta, 2010) in 1990, following the second World Climate Conference and the establishment of the IPCC.[3]

Two years later, in 1992, the UNFCCC was adopted in New York during a UN General Assembly and opened for signature at the "Rio Earth Summit". It entered into force in 1994 with a mitigation objective, to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UN, 1992). The Convention specifies that such a level should be achieved, inter alia, to ensure food production is not threatened.[4]

At the early stages of climate change policy discussions, including in the UNFCCC, there was a marked emphasis on mitigation (Gupta, 2010). Adaptation and climate resilience of agriculture received little to no attention, but the IPCC response strategies pointed out potential co-benefits (e.g. erosion control, improved water management) of mitigation measures proposed for the agricultural sector (IPCC, 1990). These proposed mitigation options with potential co-benefits include some practices related to sustainable agriculture and agroecology such as minimum- or no-till systems, perennial cover crops, reducing nitrogen fertilizer use by applying animal manure, and silvopastoral systems.

The Kyoto Protocol (UN, 1998), adopted in 1997 and entered into force in 2005, builds on the UNFCCC and does not contain any new long-term objectives or principles. It specifically mentions sustainable agriculture as a means for mitigation, yet provides no further details (Gupta, 2010). The Kyoto Protocol defined the Clean Development Mechanism (CDM) – one of the flexibility mechanisms, designed to enable parties to achieve emission reductions most efficiently – in a way that would allow using climate mitigation funds for the payment for ecosystem services. While improved soil management has a large potential for carbon sequestration and some argued that such payments could provide farmers in developing countries with considerable supplementary income, soil carbon sequestration was eventually excluded from the international carbon offset markets. The opposition to its inclusion was partially based on the claim that:

> **Soil carbon offsets were a means of putting the mitigation burden on low income developing country farmers and that farmers were unlikely to see any benefit from participating in such markets, but rather could be exposed to losing rights to their land (Lipper and Zilberman, 2017).**

The second decade of the new Millennium brought an end to the long-standing dichotomy between adaptation and mitigation, broadened the discussion from agriculture to a more holistic food system approach and led to a proper "climatization of the debate on agriculture".[5] To a large degree this was due to the systems perspective of the 2030 Agenda for Sustainable Development[6] and the Paris Agreement on

[3] Established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1998, endorsed by the UN General Assembly the same year.

[4] As stipulated in UNFCCC, art. 2: https://unfccc.int/resource/docs/convkp/conveng.pdf

[5] Stakeholder interviews for this report (see **Annex 1**).

[6] Adopted at the UN Sustainable Development Summit in New York in September 2015.

Climate Change,[7] the IPCC's increasing references to food systems in its reports as well as several research initiatives[8] bringing forward "win-win" solutions, highlighting synergies between adaptation and mitigation.

Since 2006, the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) held a number of workshops on issues related to agriculture. Agriculture was formally incorporated as an agenda item under the SBSTA in 2011. Between 2013 and 2016, five workshops on issues related to agriculture took place under the SBSTA. Finally, at COP 23 in 2017, the two permanent subsidiary bodies (SBs) of the UNFCCC – SBSTA and the SB for Implementation (SBI) – were officially requested to jointly address issues related to agriculture.[9] This collaborative process, the KJWA, was to include workshops and expert meetings, working with constituted bodies under the Convention and take into consideration the vulnerabilities of agriculture to climate change and approaches to addressing food security. The decision to establish the KJWA was hailed as a breakthrough, being the "first substantive outcome and COP decision in the history of the agenda item on agriculture" and giving unprecedented priority to the objective to "develop and implement new strategies for adaptation and mitigation within the agriculture sector" (St-Louis *et al.*, 2018). The establishment of the KJWA was the fruit of a long negotiation process, ending the divide between technical knowledge and implementation by bringing together the SBI and SBSTA.

2.2.2 Analysis of the degree of integration of agroecology into nationally determined contributions (NDCs)

NDCs are a core component of the Paris Agreement. In the NDCs, each party is requested to outline and communicate their respective mitigation and adaptation goals. A previous analysis of the NDCs carried out by Strohmaier *et al.* (2016) showed that the agriculture sector features prominently in the NDCs, with many countries highlighting the role of agriculture, forestry, fisheries and aquaculture in their economic development. Many also point to the vulnerabilities of these sectors to climate change. The agriculture sectors are able to deliver considerable adaptation and mitigation benefits and many NDCs recognize these adaptation-mitigation synergies. The systematic analysis presented here intends to identify the extent to which countries include agroecology and related approaches in their NDCs.

Out of 136 NDCs analysed, 17 countries[10] (12.5 percent) explicitly mention agroecology. Of these countries, 13 are from sub-Saharan Africa, two from Latin America and the Caribbean, one from the Near East and North Africa and one from Asia Pacific. The emphasis is clearly on adaptation, as 15 of these 17 countries, see agroecology as an adaptation strategy and only 6 see it as contributing to mitigation, mostly referring specifically to agroforestry.

African countries mention agroecology mostly in the context of soil, land and water management. For example, the Republic of Burundi (2015) aims to develop an agroecology approach for soil fertility management and soil conservation. The Republic of Rwanda (2015) seeks to employ agroecology for nutrient cycling and water conservation in order to maximize sustainable food production, while Côte d'Ivoire (2015) intends to use agroecology for reforestation and restoration of degraded lands.

In addition to the 17 countries explicitly mentioning agroecology, many countries refer to some of the elements of agroecology. The elements of agroecology highlighted most prominently are related to production aspects (diversity, efficiency, recycling, resilience and synergies); while elements referring to the socio-economic and political dimension of agroecology (circular and solidarity economy, co-creation and sharing of knowledge, culture and food tradition, human and social values and responsible governance) are largely neglected (**Figure 5**).

[7] Adopted at COP 21 in December 2015.

[8] Such as the Global Research Alliance on Agricultural Greenhouse Gases (launched in December 2009), debate on Climate Smart Agriculture, "4 per 1000" soils for security and climate initiative, a carbon sequestration initiative (launched by France in December 2015 at the COP 21).

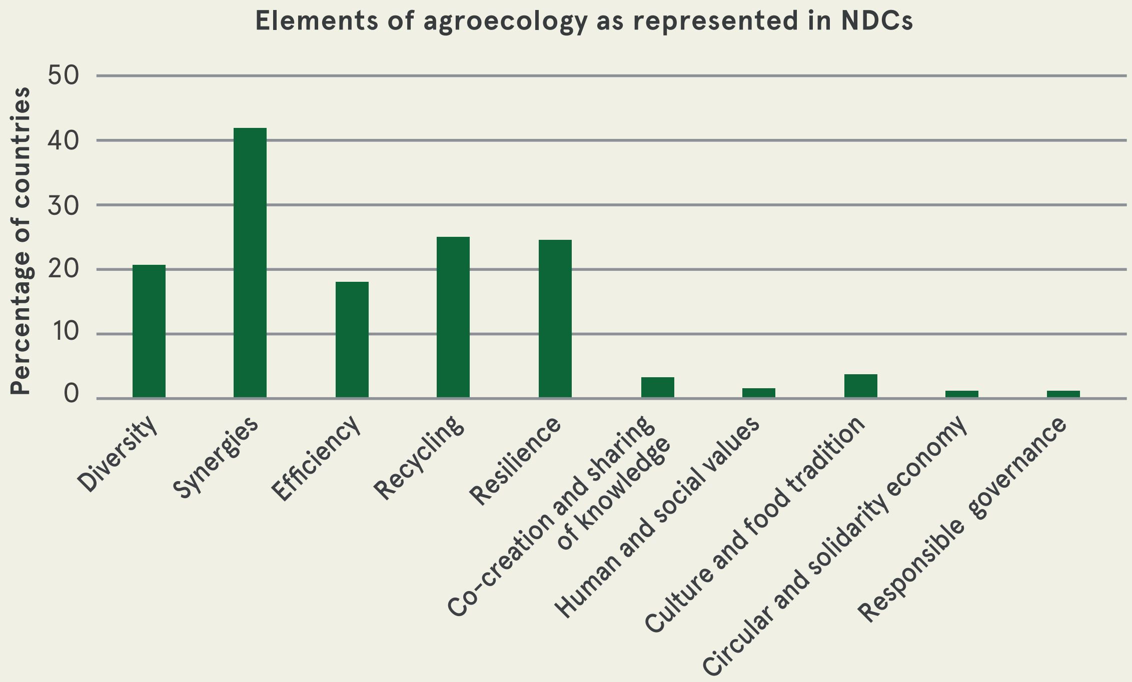
[9] Adoption of decision 4/CP.23 on the Koronivia Joint Work on Agriculture.

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

Out of the 136 NDCs analysed, only four countries refer to the co-creation of knowledge, five countries to culture and food tradition and only two countries refer to human and social values. Countries referring to these socio-economic and political elements are mainly from Latin America and the Caribbean. For instance, the Republic of Venezuela (2015) aims to mainstream agroecology into school and university curricula from pre-school to diploma level. The Republic of Honduras (2015) plans to promote the establishment of regional research centres and national outreach programs and the development of sustainable systems based on agroecology. Latin American countries, including Guatemala and Bolivia, also stand out for acknowledging the importance of and revitalizing indigenous and ancestral knowledge.

FIGURE 5.

FREQUENCY OF REFERENCES TO THE ELEMENTS OF AGROECOLOGY IN NATIONALLY DETERMINED CONTRIBUTIONS



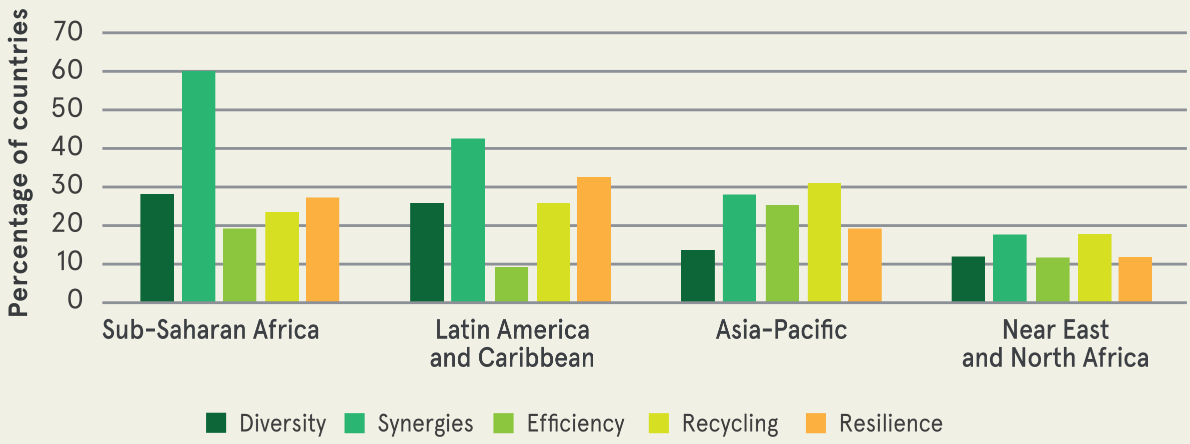
The degree to which countries highlighted different elements of agroecology as options contributing to both adaptation and mitigation in their NDCs. The majority of countries see agroecology mostly as an adaptation strategy. Mitigation is seen mostly through synergies with the use of agroforestry and efficiency in terms of reduced use of fertilizers.

The degree to which the elements of agroecology are reflected in countries NDCs differ by regions (**Figure 6**). Synergies are very frequently referred to by countries in sub-Saharan Africa (in 60 percent of the NDCs) and Latin America (41 percent). The same regions also emphasize resilience. In NDCs from the Asia Pacific region, on the other hand, efficiency and recycling figure prominently. In the NDCs from the Near East and North Africa region, none of the elements of agroecology plays an outstanding role.

Under synergy, which is the most frequently identified agroecology element, the majority of the countries refer to agroforestry, silvopastoral and mixed crop-livestock systems. In regard to diversity, most countries are aiming to employ different crop varieties and livestock breeds with more emphasis on traditional crops and livestock, which are considered more stress-tolerant and adaptable to local conditions. For efficiency, most countries aim at reducing the use of industrial (synthetic) fertilizers by adopting organic fertilizers and promoting integrated pest management. Recycling is mentioned mostly in reference to composting and crop residue reuse for soil cover and soil organic matter improvement. All of the countries in the Near East and North Africa region that included the recycling element refer to wastewater reuse in agriculture. Resilience is seen mostly through a diversification perspective; for instance diversifying agricultural activities as a contribution to enhancing farmers' resilience. In addition to diversification, many countries envision the use of agricultural insurance and establishment of micro-credit financing to increase the resilience of producers.

FIGURE 6.

PERCENTAGE OF COUNTRIES BY REGIONS, REFERRING TO DIFFERENT ELEMENTS OF AGROECOLOGY IN THEIR NDCs



2.3 CURRENT DYNAMICS IN THE KORONIVIA NEGOTIATIONS

2.3.1 The Koronivia Joint Work on Agriculture (KJWA) process and initial submissions of parties and observers

In 2017, at COP 23 in Bonn, the international community adopted a decision to have a work stream on agriculture through a three-year process named KJWA. This decision recognizes the critical role agriculture has on responding to climate change and calls for a joint work between subsidiary bodies (SBSTA and SBI) of the UNFCCC on specific elements, including through workshops and expert meetings. The elements are organized in six different topics and are addressed through submissions. The six topics are:

a) modalities for implementations of the outcomes of the five in-session workshops on issues related to agriculture and future topics that may arise from this work;
b) methods and approaches for assessing adaptation, adaptation co-benefits and resilience;
c) improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management;
d) improved nutrient and manure use towards sustainable and resilient agricultural systems;
e) improved livestock management systems; and
f) socio-economic and food security dimensions of climate change in the agricultural sectors.

Figure 7 shows the roadmap of the KJWA that foresees in-session workshops on six topics from December 2018 to November 2020.

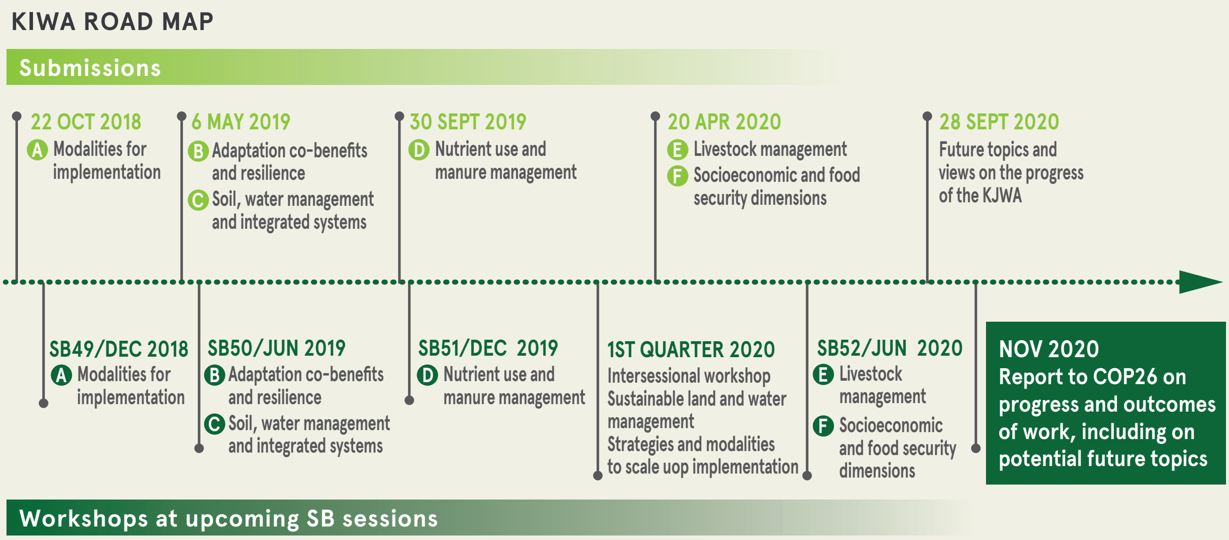
Parties, as well as observers, were invited to submit their views ahead of the adoption of the roadmap in May 2018. FAO provides a detailed analysis of the initial submissions by 21 parties and 27 observers (Chiriacò *et al.*, 2019). Here we first provide a quick overview of this analysis by FAO from an agroecology perspective and then review the more recent submissions made under various topics in the KJWA in 2019.

Many of these initial submissions focussed on the modalities of the KJWA process and on issues related to assessment, monitoring and evaluation. A number of submissions expressed the view that the KJWA is, above all, a great opportunity for sharing knowledge, experiences and best practices. Thus, some submissions include specific showcases, whereas others focus on needs and priorities for advancing on the respective workshop topic.

It is noteworthy that showcases and best practices are mostly included in the submissions of industrialized countries and the West African nation Benin. These "best practices" generally emphasize conventional agriculture, biotechnology and digital solutions but also include some agroecological practices (e.g. cover crops, no-till, recycling of drainage water, rotational grazing). On the other hand, submissions of developing countries (including from the African Group of Negotiators (AGN) the Least Developed Countries (LDCs) group, and the African states Benin, Burundi, Kenya and Malawi) usually include a list of priorities and needs to advance on the respective topics. These lists, in a considerable number of cases, make reference to practices or principles related to agroecology. Specific examples include capacity building for women and youth, reduced tillage, cover crops, crop rotation, ecosystem-based grassland management, inclusive property land rights, integrated agro-silvo-zootechnical systems, integrated soil fertility management, optimized management of crop residues, organic fertilizers and organic farming in general, reforestation, restoration of degraded lands, and valorisation of animal waste. Finally, it is important to note that only the LDC group submission highlights the need to integrate traditional knowledge.

FIGURE 7.

ROADMAP OF THE KORONIVIA JOINT WORK ON AGRICULTURE (KJWA)



Chiriacò et al., 2019a.

Parties and observers to the UNFCCC are invited to submit their views ahead of each of the workshops on the six topics agreed upon in the roadmap of the KJWA.

In the following sections an individual and systematic review of all the submissions (as well as the official workshop reports) on topics 2(a), 2(b), 2(c), and 2(d) from an agroecological perspective is presented.

2.3.2 Topic 2(a): Modalities for implementation of the outcomes of the five in-session workshops on issues related to agriculture and other future topics that may arise from this work

As the workshop title suggests, the majority of submissions and discussions focussed on modalities and processes with an emphasis on sharing of knowledge and experiences as well as support for implementation (Chiriacò *et al.*, 2019a; UNFCCC, 2019a). Concrete practices and technologies received little attention but especially observer submissions called explicitly for systemic and transformational approaches as well as enhanced inclusiveness, equity and participation.

Agroecology is specifically mentioned only in the submission by the Climate Action Network (CAN). CAN refers to agroecology in three instances, including this statement: "KJWA presentations and discussions should reflect on and direct work towards holistic efforts, including the progressive transition towards agroecology to ensure the long-term viability of agricultural systems within the natural world that they depend upon" (Climate Action Network International, 2018). Additionally, several submissions mention sustainable agriculture and the need for approaches to adaptation that create co-benefits for sustainable development. Further, individual elements of agroecology are mentioned in 53 percent (9 out of 17) party submissions and in 54 percent (7 out of 13) observer submissions (**Figure 8**). The submission of Vietnam is the most concrete, pointing out good experiences with integrated crop-livestock-aquaculture systems, referring to this as climate-smart agriculture (CSA).

FIGURE 8.

PERCENTAGE OF PARTY (n=17) AND OBSERVER (n=13) SUBMISSIONS TO THE KJWA WORKSHOP ON TOPIC 2(A) AT SB49 MAKING SPECIFIC REFERENCE TO ANY OF THE TEN ELEMENTS OF AGROECOLOGY

2.3.3 Topics 2(b): Methods and approaches for assessing adaptation, adaptation co-benefits and resilience; and 2(c): Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management

As both topics were addressed at the same session (SB50) and there was a single call for submissions on both topics, a number of submissions do not clearly separate the two topics and are therefore discussed jointly here as well. Elements of agroecology figure quite prominently in many submissions to SB50 (**Figure 9**; see also Chiriacò *et al.*, 2019b). Submissions specifically on topic 2(b) often include references to socio-political aspects of agroecology (e.g. co-creation and sharing of knowledge, human and social values and responsible governance). Views on topic 2(c) often highlight the adaptation and mitigation co-benefit potential of agroecological approaches corresponding to the elements efficiency, diversity, recycling, resilience and synergies. Culture and food traditions, as well as circular and solidarity economy, are the only two elements rarely addressed in party and observer submissions, both being mentioned in just a single observer submission each.

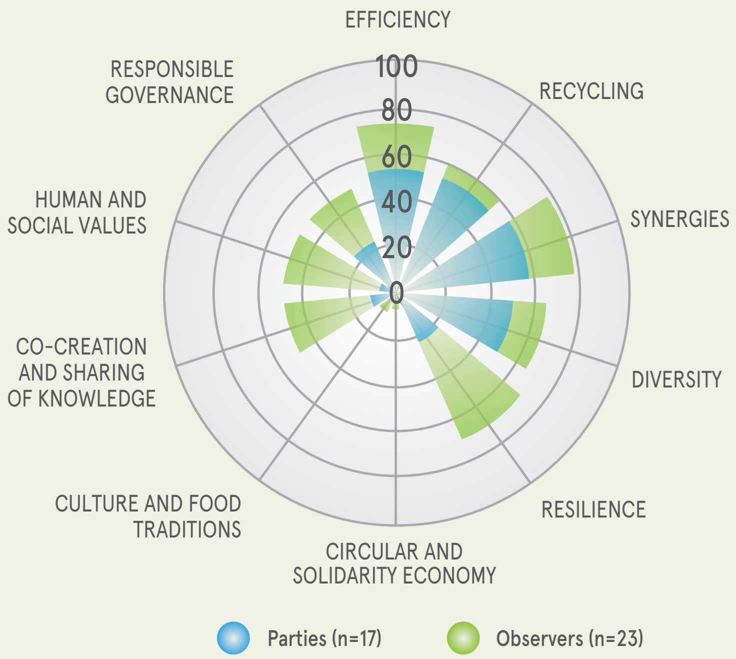
While agroecology is rarely mentioned specifically in party submissions, some contain various references to agroecological practices (e.g. Brazil, Indonesia, Kenya, Uruguay and Vietnam). However, usually, these are mentioned as singular approaches (especially agroforestry, cover crops, crop rotation, organic fertilizers and reduced tillage) and not as part of a systemic transformation of production systems. Two out of 17 party submissions – Kenya and European Union (EU) – refer to agroecology by name. While Kenya describes it as a CSA measure, the EU mentions agroecology as a transformational approach as well as an example of "sustainable land/soil management practices" (European Union, 2019).

Agroecology is mentioned explicitly in 22 percent of observer submissions (5 out of 23) on topics 2(b) and (c) (Biovision & FiBL, Climate Action Network, GenderCC, GIZ, YOUNGO). In all of these, agroecology plays a rather central role and is decisively endorsed. Additionally, nearly all other observer submissions (all but the World Business Council for Sustainable Development) include at least one element of agroecology, without mentioning it by name.

The enhanced interest in agroecology and other transformative approaches is also demonstrated by the workshop reports drafted by the UNFCCC secretariat. The report on topic 2(b) states that "it is generally accepted that successful adaptation to climate change requires transformation and paradigm shifts" and specifically mentions agroecology two times (UNFCCC, 2019b). The report on topic 2(c) even refers eight times explicitly to agroecology, including thrice in the section "Summary of discussions and the way forward" (UNFCCC, 2019c).

FIGURE 9.

PERCENTAGE OF PARTY (n=17) AND OBSERVER (n=23) SUBMISSIONS TO THE KJWA WORKSHOPS ON TOPICS 2(B) AND (C) AT SB50 MAKING SPECIFIC REFERENCE TO ANY OF THE TEN ELEMENTS OF AGROECOLOGY



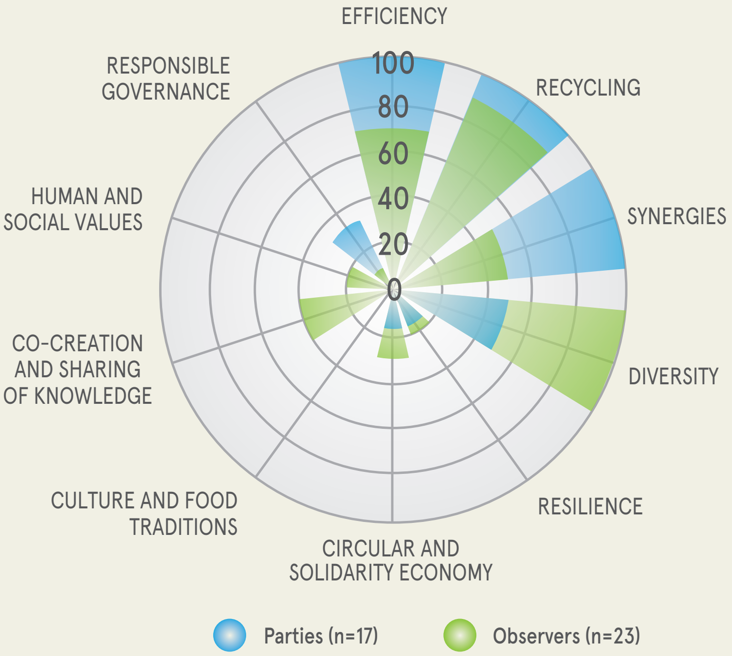
2.3.4 Topic 2(d): Improved nutrient use and manure management towards sustainable and resilient agricultural systems

As of 15 November 2019, six parties and ten observers submitted their views on topic 2(d). A number of submissions point out clear thematic overlaps with topic 2(c). However, in contrast to the discussion on soil health, the emphasis in most submissions on topic 2(d) is limited to the agroecology elements efficiency (increasing efficiency of fertilizer use, especially through precision farming) and recycling (substituting synthetic with organic fertilizers, especially manure). Additionally, three parties and three observers see nutrient management as an entry point for integrated crop-livestock systems and harnessing the resulting synergies. In this regard, the EU specifically mentions agroecology. Apart from this, most party submissions include rather few references to systemic approaches for nutrient management. Brazil and the EU are partial exceptions, highlighting the multiple benefits of cover crops, crop rotation, green manure, intercropping, recycling of organic waste material and reduced tillage for enhancing the resilience and sustainability of the agricultural sector. On the other hand, several parties argue for increasingly integrating discussions on different KJWA topics as well as enhancing synergies with other discussions within and outside of the UNFCCC. Further, a number of submissions highlight the need for stronger multi-stakeholder processes, especially the involvement of scientists and farmers.

This notwithstanding, the focus is on the technological components of agroecology and the socio-economic dimensions are mostly neglected (**Figure 10**). Again, a partial exception is the EU submission, which includes a specific sub-section on circular economy. All observer submissions point to the link between soil nutrient management and the agroecology element diversity and synergy (especially crop rotation, intercropping and functional biodiversity). It is noteworthy that actors such as FAO and the Farmers Constituency highlight the "need for a holistic approach for nutrient use and manure management". FAO also specifically promotes agroecology and "offers support to countries seeking to undertake transformative changes in agricultural sectors in the face of climate change" (FAO, 2019b). Further, agroecology is specifically endorsed by CAN, IFOAM, Biovision and FiBL, Brighter Green as well as CropLife International, although the respective organizations' definitions of the term differ to a considerable degree. While the former non-governmental organisations (NGOs) highlight the holistic and transformative characteristics of agroecology, CropLife International reduces the concept to the technological elements and argues for agroecology's compatibility with biotechnology.

FIGURE 10.

PERCENTAGE OF PARTY (n=6) AND OBSERVER (n=10) SUBMISSIONS TO THE KJWA WORKSHOP ON TOPIC 2(D) AT SB51 MAKING SPECIFIC REFERENCE TO ANY OF THE TEN ELEMENTS OF AGROECOLOGY



2.3.5 Views of key stakeholders on the current discussion on the agriculture and climate change nexus in the United Nation Framework Convention on Climate Change (UNFCCC) processes, including the Koronivia Joint Work on Agriculture (KJWA)

In order to understand opinions from a broad range of stakeholders engaged in the UNFCCC processes and in particular in KJWA, different experts were interviewed to share their opinions and expectations and what they perceive could be the role of agroecology in KJWA.

All interview partners agree that the discussion on the agriculture-climate change nexus was delayed for too long and that, even now, discussions at the UNFCCC processes are not yet about which agricultural model to promote. Thus, neither conventional agriculture nor agroecology or other transformative approaches are emphasized. The current debate seems to be really on the general modalities of implementation (rather than the "who" and "how": responsibilities and financing) and usually do not go sufficiently in-depth and detail regarding concrete approaches (the "what": appropriate technologies). Several interviewees feel that "discussions in the UNFCCC often remain vague and not precise".

Nevertheless, many interviewees perceive that transformational approaches are becoming increasingly important for both parties and observers, "at least in the wording although the reality usually remains at essentially a business as usual model". Hence, it seems that *de facto* most parties still aim for incremental change within conventional agricultural systems. Interviewees often explained this by the fact that countries strive to protect their own interests and to have a competitive edge on the global market. The majority of interviewees agree that several observers are a lot more demanding regarding the promotion of transformative approaches, such as agroecology.

A number of interviewees highlight that agroecology is "clearly gaining momentum", although it still remains a controversial topic. As a representative of FAO phrases it: agroecology is a "difficult agenda to move forward, with big powerful countries with dominant industrial agricultural systems" opposed to it in principle. Further, a negotiator reflected: "Agroecology is increasingly being mentioned but technological details etc. do not receive sufficient attention and detailed explanations are mostly lacking". Generally, several interviewees mentioned they were missing a stronger science-policy interface in the KJWA workshops and feel that capacity-building and awareness-raising is often missing for negotiators to be sufficiently equipped to tackle the different topics discussed.

Finally, different interviewees expressed confusion or even frustration regarding the myriad of concepts and approaches without clear distinction (e.g. agroecology, CSA, conservation agriculture, ecosystem-based adaptation, nature-based solutions, and SLM). Some see it as the mandate of UN institutions, such as FAO, to clarify, show evidence, and showcase different options, thus providing a global framework. On the other hand, speaking from a farmer perspective, an interviewee flags that "it's not about black or white but rather the diversity of options" and "the core of the debate should focus on one factor that these concepts should all have in common: profitability and the need for improving farmers' wellbeing".

2.4 OUTLOOK: FUTURE POTENTIAL OF AGROECOLOGY TO BE BACKED BY UNFCCC

"Koronivia gave soul to agriculture in the climate change discussions", and interviewees all agree that as the only active agenda point focusing solely on agriculture, "the process itself is extremely valuable and important". Yet some regret that "discussions do not lead to any concrete decisions or actions". An interviewee highlights that the Koronivia process is currently missing the grasp of transformational change of the agricultural system as it limits itself to food security, not embracing the entire food system. There is a lot of hope for post-COP 25, as this is perceived as "a big turning point for agriculture within the UNFCCC processes", the "test phase for the KJWA to show it is useful" and make it a "trigger of change".

There are diverging views on the question of whether agroecology has a chance to be promoted in the KJWA outcomes. Some, especially negotiators and researchers, feel it as "quite possible". They highlight the numerous interventions on agroecology during workshops and in submissions from the Global North and South (regarding soil-related issues for example, as shown in **Section 2.3.3**) as well as the inclusion of agroecology in the IPCC Special Report on Climate Change and Land. Even though they may not be promoted by name, some interviewees are sure that agroecological practices and principles will play an important role in any conclusions and outcomes.

A majority, however, express more doubts and see it as "unlikely" for different reasons. A negotiator highlights that agroecology is "still perceived as being too idealistic and dogmatic and most actors are obliged to balance the opinions and demands of different interest groups". A researcher mentions not expecting "such a level of detail on technologies and approaches but rather outcomes on modalities and processes", an NGO representative mentions that "agroecology as a solution or system is not very prominent in the debates". Key barriers for enhanced integration of agroecology in the international climate change policy debates are described in text **Box 1**.

Nevertheless, it is important to note that many interviewees from different backgrounds insist on the "strong need for the engagement of people advocating on agroecology in this debate". Many highlight that "any effort to have this on the agenda in the discussion is important". Also, some mention that discussions on agroecology will shape and influence agricultural development activities of member states, through the promotion of country experiences and best practices. Examples of what worked in countries being the most convincing argument.

BOX 1: KEY ISSUES HINDERING THE SCALING-UP OF AGROECOLOGY IN THE CLIMATE CHANGE DISCUSSIONS

- The wording often being very political.
- The absence of a common understanding, the lack of sensitization, visibility and communication on agroecology, in particular to some key stakeholders (i.e. key investors and donors are currently missing in the climate discussions).
- Doubts prevail regarding scientific evidence for agroecology, highlighting the importance of discussing technological details during side-events.
- The difficulty in having a proper spokesperson for agroecology in climate discussions, due to strong resistance by some influential stakeholders.
- There is still a lot of reluctance to consider the entire food system in its globality.
- The absence of international trade from the debate on climate change and agriculture (only addressing "non-market approaches") and the dogma to not question the current role and form of trade.
- The lack of a common understanding of the boundaries between the multiplicity of different concepts (agroecology, CSA, conservation agriculture, ecosystem-based adaptation, nature-based solutions, etc.).
- The focus on farm-level carbon and methane emissions in climate change discussions, when a key entry-point for agroecology is land-use at a territorial scale.

All interviewees agree that the UNFCCC framework (including KJWA) is one of the right places to push for a more sustainable food system, including to scale up agroecology, but not the only one. It is key to seize the opportunity of the climate change momentum to open discussions on the transformation of the agricultural model to achieve improved environmental performance and to bring back complexity within agricultural systems. But, "climate alone is not enough, or else it will not be truly transformational". It is also key to focus on other related issues, and therefore other arenas and fora as well, such as biodiversity and food security. This highlights the issue of the compartmentalization of the different topics and the need to build bridges between different existing conventions and fora (e.g. UNFCCC, CFS, Convention on Biological Diversity (CBD), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)).

Currently, there is a lot of hope for the scaling-up of agroecology. This promising turning point is partially enabled by the IPCC Special Report on Climate Change and Land, advocating for a transformation of the food system. This report provides a clear understanding of the convergence of different options, highlighting their co-benefits. It particularly focuses on solutions concerning soils and forests, for which agroecology integrates many of the solutions and tackles many of the challenges exposed. It clearly promotes agroecological practices, and shows how it can contribute to enhancing farmers resilience. Many interviewees highlight that this report is a very positive basis for scaling-up agroecology within the climate change discussions, as the IPCC reports have an outstanding weight in climate change debates.

A combination of other elements brought forward by the interviewees shows a promising road towards the scaling-up of agroecology. For instance, the accelerating convergence between scientific evidence and civil society mobilization was mentioned as key to making change happen. Further, it was pointed out that there is an increasing convergence between the three "Rio Conventions" (CBD, United Nations Convention to Combat Desertification (UNCCD) and UNFCCC) creating momentum for integrative and systemic approaches. Finally, there is a growing emphasis on nature-based solutions as highlighted in the IPCC land report (IPCC 2019), the UNCCD-SPI report on carbon benefits of SLM (Chotte *et al.*, 2019) and the global assessment report of IPBES (IPBES, 2019).

2.5 CONCLUSIONS: POTENTIAL TO INTEGRATE AGROECOLOGY IN INTERNATIONAL CLIMATE CHANGE POLICIES

Only recently the link between agriculture and climate change began to be properly articulated at the international policy level and finally, the dichotomy between climate change mitigation and adaptation seems to have been largely overcome. The establishment of the KJWA was a breakthrough as it brought an unprecedented emphasis on climate change – agriculture nexus and the potential of agriculture to contribute to both mitigation and adaptation simultaneously.

A detailed analysis of 136 NDCs and all submissions to the first four KJWA workshops demonstrate that a considerable number of countries and stakeholders from different backgrounds see agroecology and related approaches as a promising means for reaching adaptation and mitigation targets and at the same time increase the resilience of the food systems. Individual elements of agroecology, particularly in regard to soil health and natural resource cycles, are perceived as auspicious approaches. The systemic nature of agroecology and especially its socio-economic and political elements receive far less attention. Submissions by observers to the UNFCCC, especially those of some CSOs, are much more demanding and call for a fundamental transformation of the food system. Such transformation is also acknowledged by the UNFCCC secretariat, stating that "it is generally accepted that successful adaptation to climate change requires transformation and paradigm shifts" and by the EU referring to agroecology as a transformational approach as well as an example of "sustainable land/soil management practices". Also, recent reports by the IPCC, the UNCCD-SPI and the IPBES indicate an increasing convergence of the three "Rio Conventions" and demonstrate a shared focus on transformative approaches as well as nature-based solutions.

Based on these findings, it is not surprising that many of our high-level interview partners from diverse institutions highlighted that agroecology is gaining momentum. However, given the complex political economy underlying decision-making under the UNFCCC and the still contentious nature of agroecology, few believe that agroecology will be specifically promoted in an official outcome of the KJWA. Many believe that it is rather likely that individual elements or practices of agroecology will be promoted under a different umbrella term, such as ecosystem-based adaptation, CSA or nature-based solutions. It is key to prevent the risk that an official outcome on agroecology gets stripped of its social, economic and political dimensions and hence of its core holistic, systemic and transformative nature, which is fundamental for its potential to build resilience to climate change.

CHAPTER 3

CHAPTER

3

META-ANALYSIS: POTENTIAL OF AGROECOLOGY TO ADAPT AND INCREASE RESILIENCE TO CLIMATE CHANGE

3.1 INTRODUCTION

In this section we investigate how robust the knowledge base for the various claims on agroecology as a strategy for climate change adaptation and mitigation co-benefits is. As laid out in the previous chapters, agroecology is increasingly perceived as a promising approach to address climate change. However, the knowledge base for such claims is not always clear and the debate is often dominated by ideological and value-based rather than scientific arguments. While a huge number of case studies and summarising reports illustrates the potential of agroecology for increased sustainability and climate change adaptation in particular (Côte *et al.*, 2019; Sinclair *et al.*, 2019; IAASTD, 2009), the overall evidence-base lacks systematic scientific syntheses of the key indicators for agroecology as a comprehensive approach. This contrasts with the situation of organic agriculture, for example, where a number of recent meta-analyses on yields, financial performance, soil organic carbon and other environmental aspects is available (Gattinger *et al.*, 2012; Crowder and Reganold, 2015; Seufert and Ramankutty, 2017; Sanders and Hess, 2019; Seufert, 2019). Such robust scientific evidence-base is however central for triggering any significant policy support for agroecology and farmer adoption when stronger calls are voiced that agricultural policies should become more evidence- and results-based. This chapter aims to close this knowledge gap on the performance of agroecology with regard to climate change adaptation by compiling and analysing the scientific evidence from this rich body of existing knowledge on agroecology.

3.2 METHODOLOGY

To synthesise this evidence, the analysis draws on two types of results. First, there is a considerable number of case studies that assess the climate change adaptation potential of production systems which are judged agroecological by the authors. An extensive literature search on those in English, Spanish, French, Portuguese and Italian was undertaken, and only the studies that a) were peer-reviewed, b) contained information on an agroecological system in comparison to some baseline system, and c) provided quantitative evidence for the relative performance regarding at least one indicator for climate change adaptation and resilience (**Chapter 1.3**) were retained. These studies are referred to as “single system comparison studies”.

Second, there is a huge number of case studies that analyse how agricultural production systems, practices and characteristics that strongly relate to agroecology or some of its key elements (but without referring explicitly to this term) correlate with indicators of climate change adaptation and resilience. Examples are comparisons of organic versus conventional production systems with respect to yield stability; comparisons of different levels of species richness in agro-ecosystems with respect to total biomass production; comparisons of systems with organic fertilizers to such with mineral fertilizers with respect to soil fertility; or comparisons of how systems with a special focus on soil fertility perform in the face of extreme events if compared to conventional systems. This second type of case studies has repeatedly been synthesized in several meta-analyses and reviews on various topics. Thus, the search was not targeted at these underlying case studies specifically, but directly draw on the results from the corresponding meta-analyses and reviews. By this, the analysis also covers the knowledge based on case studies that do not explicitly refer to agroecology but to some of its key components as captured in the ten elements of agroecology (FAO, 2018b) (for a full description of the terms, see **Annex 2.1**).

This analysis employs the notion of agroecology used by FAO, structuring it along the ten elements embracing agronomic, environmental, social, economic and institutional dimensions (FAO, 2018b) (see **Chapter 1.3** and **Figure 2**). The performance analysis regarding climate change adaptation refers, instead, to the indicator framework implemented in the SHARP climate resilience assessment tool (Cabell and Oelofse, 2012; FAO, 2015) and the ten performance indicators proposed by the global analytical framework for the multi-dimensional assessment of agroecology (FAO, 2019b).

It is key to highlight that this approach may result in two types of bias. First, the review on single case studies does not cover any study that is not self-declared agroecological. However, the studies without reference to agroecology are covered in both meta-analyses and reviews, keeping in mind that ultimately this bias limiting the choice of case studies does not result in biases within the knowledge base covered. Second, the meta-analyses and reviews may cover some of the single agroecological case studies as well. However, given the low number of the latter compared to the huge number of studies covered in these meta-analyses and reviews, this potential double-count will not result in any relevant bias. For the detailed methodology, please see **Annex 2**.

3.3 RESULTS

As explained above, we did an extensive literature search on agroecological case studies in various languages. This resulted in the considerable number of 185 studies of potential interest for our review. It then turned out, however, that only a few of these agroecological studies met our restrictive inclusion requirements. We emphasize again, that we have chosen to be rather restrictive and apply high standards to the studies included, with the aim to provide a robust knowledge basis that cannot be criticised from being biased in favour of agroecology. Furthermore, the studies retained covered a vast heterogeneity of cases. Thus, it has not been possible to do any formal synthesis of those in the form of a statistical meta-analysis. On the other hand, we found a considerable number of meta-analyses and reviews on production systems, practices and characteristics that closely relate to agroecology and hence decided to base our analysis primarily on those rather than on the agroecological case studies. In the following, we present the results from these reviews first, then addressing the single system comparison studies.

3.3.1 Meta-analysis and reviews

We identified 34 quantitative meta-analyses and 19 more descriptive reviews. From the meta-analyses, some clear patterns emerge.

First, key practices and characteristics of agroecological production systems, such as the use of organic fertilizers, higher crop diversity, low-input systems, organic farming or agroforestry significantly correlate with good performance regarding a number of soil characteristics and biodiversity aspects (e.g. soil organic carbon content, soil biodiversity, soil microbial biomass and activity, nematode and earthworm abundance, and species richness), which are central aspects of climate change adaptation (FAO, 2015; IPCC, 2019) (see also **Figure 11**).

Second, most of the evidence relates to the performance of organic agriculture, agroforestry and practices related to increased crop diversity and organic fertilizer use. Not much evidence is provided on the performance of societal and social aspects of agroecology regarding indicators related to climate change adaptation. One exception is (Crowder and Reganold, 2015) reporting on the profitability of organic agriculture, measured via gross returns, benefit/cost ratio and net present values.

Third, clear results can also be seen on mitigation co-benefits of the key practices and characteristics of agroecological production systems, which consistently report positive significant effects on soil carbon contents.

Fourth, yields often tend to be lower in low-input systems than in conventional reference systems they are compared to. This is the case for organic agriculture, for example, which is an exemplary production system that in many agronomic aspects shows close similarities to agroecology, and for which more scientific evidence is available due to its clear definition. For organic agriculture, also yield stability is lower than in the conventional baseline. This can be traced back to overall lower nitrogen fertilization levels in organic than in conventional agriculture. Comparing studies with similar fertilization levels only, yield stability does not any longer differ significantly, while yields are still lower in organic production (albeit less so than with common conventional average, i.e. higher, fertilization levels) (Knapp and van der Heijden, 2018). On the other hand, certain key characteristics of agroecology such as the different diversity aspects (e.g. agrobiodiversity; crop diversity in crop rotations, intercropping, grasslands, etc.; and partly also agroforestry, which is often a system with higher diversity) correlate with higher yields and higher yield stability through time. This may indicate that increased diversity in current organic systems cannot fully compensate for reduced nitrogen supply, as far as yields and yield stability are concerned, and diversity in organic agriculture thus should be further supported. It also indicates where agroecology with its much stronger focus on diversity, often differs from organic agriculture.

FIGURE 11.

COMPILATION OF THE RESULTS FROM THE META-ANALYSIS, THE VALUES SHOW CHANGES IN COMPARISON TO THE BASELINE – PART 1 (SEE ANNEX 2.2 FOR THE COMLPETE COMPILATION AND REFERENCES)

		INDICATORS FOR CLIMATE CHANGE ADAPTATION												
		SOIL HEALTH						BIODIVERSITY		PLANT PROTECTION				
		Soil organic carbon (sequestration and content)	Total soil N	Soil loss	Soil fertility	Soil microbiome (activity and biomass)	Soil biodiversity (microbial diversity and nematode abundance)	Species richness/ abundance/ diversity	Stability of species richness/ abundance	Natural plant protection	Level of biological control	Animal pest abundance	Weed abundance	Pathogen abundance
Agroecological practices	Organic agriculture	✓		✓ (green)			✓ (green)	✓	✓		✓ (green)	✓ (green)	✗ (red)	✓
	Low-input systems						✓	✓						
	Agroforestry (incl. silvopast.)			✓	✓	✓		✓						
	Reduced tillage	✓	✓		✓	✓								
	Cover crops	✓	✓											
	Organic fertilizers (incl. residues)	✓	✓		✓		✓	✓ (green)						
	Crop rotation/ diversity/ intercropping	✓	✓			✓	✓	✓		✓				
	Grassland diversity													
	Practices enhancing biodiversity & complex landscapes									✓				

✓ Significantly better
✗ Significantly worse
0 No effect
✓ (green) Better, but not significant
✗ (orange) Worse, but not significant
Grey: indicators referring to temporal stability/variability

FIGURE 11.

COMPILATION OF THE RESULTS FROM THE META-ANALYSIS, THE VALUES SHOW CHANGES IN COMPARISON TO THE BASELINE – PART 2

		INDICATORS FOR CLIMATE CHANGE ADAPTATION										
		PRODUCTIVITY								EMPLOYMENT		HEALTH
		Total biomass production	Stability in total production	Yield	Yield stability	Pollination services	Resource use efficiency	Ecosystem services stability	Profitability	Stability of costs and profits	Rural employment	Exposure to pesticides
Agroecological practices	Organic agriculture			✗	✗		0			0	✓	✓
	Low-input systems			✗								
	Agroforestry (incl. silvopast.)	✓										
	Reduced tillage	✗ (worse, not significant)		✓ (better, not significant)								
	Cover crops											
	Organic fertilizers (incl. residues)	✗		✓ (better, not significant)								
	Crop rotation/ diversity/ intercropping		✓	✓ (better, not significant)	✓				✓	✓	✓ (better, not significant)	
	Grassland diversity			✓								
	Practices enhancing biodiversity & complex landscapes			✓		✓	✓	✓				

✓ Significantly better
✗ Significantly worse
0 No effect
✓ Better, but not significant
✗ Worse, but not significant
Grey: indicators referring to temporal stability/variability

For several results, further differentiation is warranted, e.g. regarding climate zones or soil types. Thus, for example, more complex crop rotations in combination with crop residue retention and no-tillage lead to significantly higher yields in dry areas (by 7-8 percent) while this is not the case in other contexts (Pittelkow *et al.*, 2015). This study is from a context of conservation agriculture, though, which not always can be related to an agroecological practice, depending on how plant protection and weed management is implemented.

The 19 qualitative reviews provide ample details on certain aspects that are also well-covered by the meta-analyses, such as the relation of organic amendments and soil fertility or diversity and production. Some address aspects not widely covered in the meta-analyses, such as the effect of agroecological practices on various indicators for financial capital (D'Annolfo *et al.*, 2017) and many other economic aspects (Van der Ploeg *et al.*, 2019), and some address aspects that are not covered at all in the meta-analyses such as water use, and present information on single crops, such as the System of Rice Intensification (SRI). The results generally point to the good performance of agroecology and related practices and characteristics. However, these reviews' results are based on an informal assessment of a wealth of anecdotic evidence and not rooted in systematic reviews of meta-analyses or robust systems comparisons studies, therefore we give them less weight relating the robustness of results. Besides, providing further, topically broad and for each topic detailed, albeit not systematically and statistically compiled and analysed evidence, this highlights the research gaps in the current meta-analyses: firstly, on the issue of water use and water management in different agroecological contexts and how various practices and characteristics perform with regard to this; secondly, on single central crops when grown in different agroecological contexts, such as rice, cassava, soy or wheat.

3.3.2 Single system comparison studies

The literature search on single system comparison studies resulted in 185 studies fitting the search terms (basically various forms and combinations of "agroecology" plus related terms such as "permaculture", "regenerative agriculture" etc. and "climate change"; see **Annex 2.3**). From these, we identified only 17 single system comparison studies that fulfilled all selection criteria for inclusion in the analysis (peer-reviewed, clear baseline to which the agroecological systems are compared to, being the original data source (to avoid double-counting – there is a number of studies that do not provide new data but refer to other studies), providing evidence for the relative performance). These reported 83 cases of implementation of agroecological practices. These cases covered a huge heterogeneity in agricultural production systems, practices, crop types, geographic location, pedo-climatic characteristics, political, social and cultural contexts, etc., and also in the indicators covered. In consequence, this heterogeneity in combination with the low case numbers (many indicators were reported per study only, not for single practices) hindered a thorough systematic meta-analysis. We thus present a descriptive analysis of these results, which nevertheless allows to identify several noteworthy patterns.

First, the distribution of practices covered in the case studies shows a focus on "agroforestry", and then also on "efficient water use", "biomass recycling" and "crop rotations", followed by "Nitrogen fixation", "cover crops" and "adoption of organic and low-input systems" (**Figure 12**).

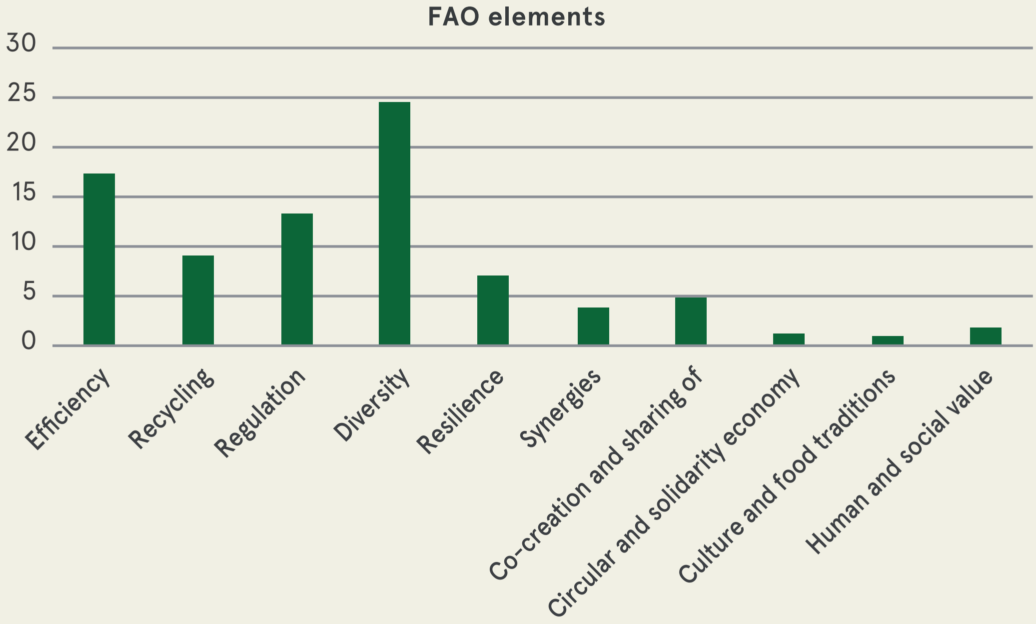
FIGURE 12.

DISTRIBUTION OF AGROECOLOGICAL PRACTICES IN THE SINGLE SYSTEM COMPARISON STUDIES, ORDERED ACCORDING TO THE TEN ELEMENTS OF AGROECOLOGY THEY REFER TO, FROM LOWER (LEFT) TO HIGHER ELEMENTS (RIGHT) (SEE SECTION 1.4.1)

Second, on a more aggregate level, adopting the FAO ten elements as a lens to the analysis of the practices, we can notice a strong emphasis on the six "production-related" elements of agroecology (i.e. efficiency, recycling, regulation, diversity, resilience, synergies, in total covering 90 percent), with a focus on diversity and efficiency (together 50 percent). The element "co-creation and sharing of knowledge" is reported 5 times (6 percent), while the other more encompassing elements, "circular and solidarity economy", "culture and food traditions" and "human and social values" are almost missing (**Figure 13**). Nevertheless, the elements covered closely relate to various aspects of increased resilience and thus, despite not resulting in a holistic coverage of agroecology, contribute to climate change adaptation. Furthermore, many elements relate to increased mitigation co-benefits, such as reflected in increased efficiency, reduced use of mineral fertilizers or increased soil carbon levels that are reported in the case studies.

FIGURE 13.

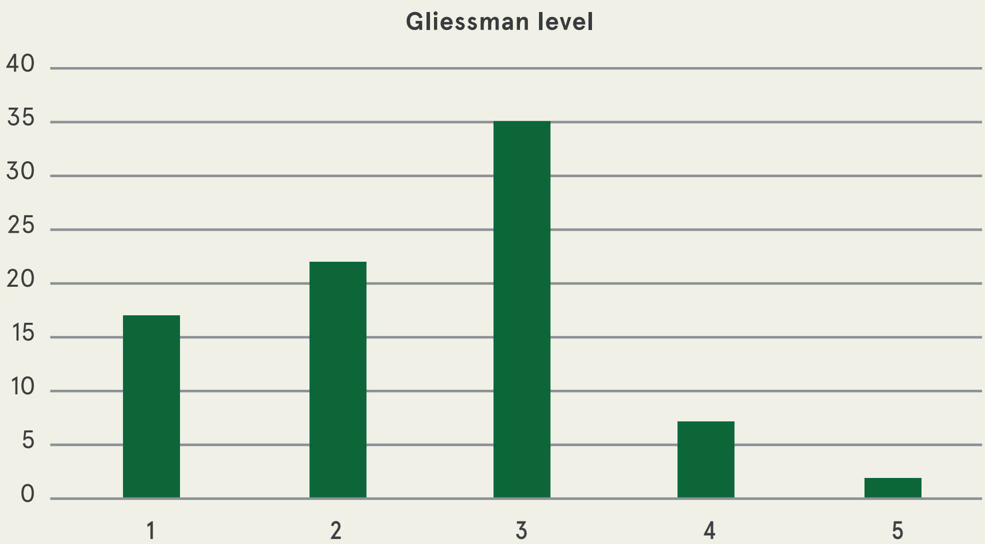
DISTRIBUTION OF FAO ELEMENTS OF AGROECOLOGY IN THE SINGLE SYSTEM COMPARISON STUDIES



This lack of coverage of systemic aspects is also reflected when relating the practices to the Gliessman levels (**Figure 14**). About 40 percent of the practices reported in the studies refer to Gliessman level 3, i.e. to "Redesign the agroecosystem so that it functions on the basis of a new set of ecological processes" while almost 50 percent refer to the lower levels one and two, where no re-design of production systems is taking place. Only about 10 percent of practices refer to level four ("Re-establish a more direct connection between those who grow our food and those who consume it") and two only relate to level five ("[...] build a new global food system [...]").

FIGURE 14.

DISTRIBUTION OF GLIESSMAN LEVELS IN THE SINGLE SYSTEM COMPARISON STUDIES



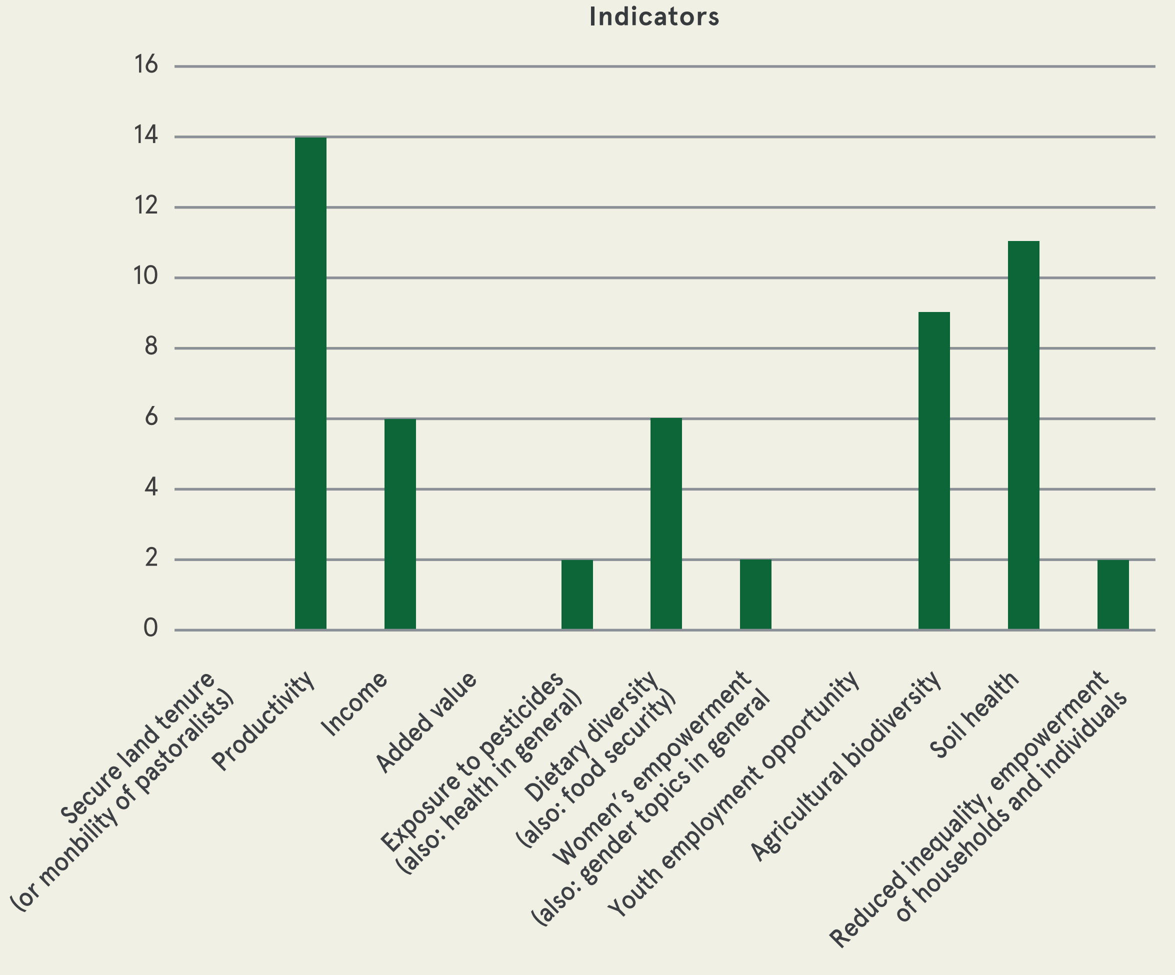
The analysis of these case studies thus shows that there is incomplete coverage of the different aspects of agroecology. Most studies focus on practices that are relevant in agroecology, but taken for themselves do not provide holistic coverage of agroecology as they miss a whole food-system focus. Another aspect of restricted coverage relates to production systems. The studies mainly focus on crop production and silvopastoral livestock systems, while non-timber forestry products and aquaculture are lacking, which also reflects that agroecology is not prominently discussed in these contexts.

Figure 15 illustrates the extent in which some of the criteria of performance of agroecology of the Tool for Agroecology Performance Evaluation (TAPE), which is a test version of the FAO Global Analytical Framework for Multi-Dimensional Assessment of Agroecology (FAO, 2019c), are reported in the single system comparison studies. Some papers used different indicators than suggested by the FAO global analytical framework to capture some criteria, such as "wealth", which we then subsumed under the corresponding criterion (here "income") in the graph.

The studies focus mainly on "productivity" (i.e. yields, 27 percent of cases reported), "soil health" (21 percent) and "agricultural biodiversity" (17 percent), followed by "food security" and "income" (each at 12 percent). This captures four of the criteria from the economy, environment and health and nutrition dimensions of the framework, which most closely relate to climate change adaptation (criteria: soil health; agricultural biodiversity; income; productivity).

FIGURE 15.

NUMBER OF REPORTED CASES THAT MATCH THE RESPECTIVE INDICATORS IN THE SINGLE SYSTEM COMPARISON STUDIES



The single system comparison studies generally report improved performance of the agroecological systems with respect to the respective baselines, i.e. the case study location-specific "average" (traditional, conventional) production system. Thus, they consistently report higher diversity and improved soil characteristics with corresponding positive consequences for climate change adaptation, such as reduced erosion, increased water holding capacity and higher soil moisture conservation. In some cases, differences are not statistically significant, but in only one case worse performance is reported, namely in yields. Several important aspects are hardly or not covered though, such as nutritional aspects of food security.

Finally, a third of the studies explicitly report climate change mitigation co-benefits from carbon sequestration in soils and living biomass as well as from reduced fertilizer use. About 50 percent of the single system comparison studies highlight the role of institutional aspects, such as the enabling environment for the adoption of agroecological practices, knowledge transfer and exchange, co-creation of knowledge, (participatory) extension and advisory services and access to financial and other livelihood capital. The studies emphasize that without these enabling environment elements, agroecological practices would not have been adopted and their adaptation and mitigation benefits could thus not have been realised.

The evidence from these studies on the climate change adaptation-related performance criteria of agroecology is mainly based on cases where specific agronomic aspects, such as alternative production in agroforestry systems or more efficient water use are addressed. There is, however, a general lack of holistic systemic assessments addressing most or all aspects in one consistent approach (about a third of the studies analysed follow such approach). Thus, it remains open whether the good performance reported in these studies relates to agroecology in an encompassing way or merely to these specific aspects (i.e. being agroforestry, adopting a specific water management regime, etc.) of it. Furthermore, as none of these studies specifically test for the role of institutional aspects, it remains open how much of the good performance is owed to well-organized knowledge transfer, extension and co-creation of knowledge, etc. and how much is owed to these cases being "agroecological".

3.3.3 Reviews on advisory services knowledge co-creation and knowledge transfer

The central role of knowledge transfer for the adoption of agroecological practices, and the fact that knowledge co-creation is an integral part and knowledge intensity the main barrier to the adoption of agroecology, motivated a specific search for meta-analyses and reviews for those (see **Annex 2.1**). Knook *et al.* (2018) present a systematic review of evaluations of participatory extension programmes, to better understand and provide evidence on the effectiveness of capacity development interventions that are based on farmer demand and participation. They find a strong positive effect for this, although with the scientific robustness of evaluations being variable. A similar pattern of largely positive effects on mostly economic indicators can be seen in the review of Davis *et al.* (2012) of farmer field school (FFS) impact evaluations. A third review by Pamuk, Bulte and Adekunle (2014), investigating innovation platforms (IPs) effectiveness in supporting the adoption of innovations across eight African countries using primary data. They found a robust positive impact on the adoption of crop management innovations, but not so much for other areas of innovation, such as the ones related to soils and fertility management and other more complex agro-ecological practices such as crop rotations. Importantly, the success of IPs seems to strongly depend on the presence and type of social capital and the relevance of specific context characteristics for innovation delivery. This is generally widely acknowledged (Dror *et al.*, 2016; Schut *et al.*, 2018) and can inform agroecology related programmes and policies.

3.4 DISCUSSION OF THE POTENTIAL OF AGROECOLOGY TO TACKLE CLIMATE CHANGE

3.4.1 Increasing adaptive capacity, reducing vulnerability, and mitigation co-benefits

With the wealth of significant and positive results as synthesized in **Figure 11**, our analysis provides robust evidence on the performance of agroecological practices and key elements of agroecological agroecosystems with respect to central aspects of climate change adaptation and resilience, in particular on soil health and biodiversity, but also on income and productivity. Furthermore, the improved soil health correlates with higher soil organic carbon levels, with corresponding mitigation co-benefits.

These findings provide a robust basis for supporting agroecological production systems and practices as promising approaches for climate change adaptation in agriculture, with mitigation co-benefits. Such support is however faced with the challenge of not having a clear-cut definition of agroecology that can be certified as organic agriculture. Thus, it is central to identify clear characteristics and indicators that would trigger such support, which is the main goal of TAPE still undergoing field testing.

TAPE could be organized through a results-based approach, i.e. conditional on good performances in key indicators that correlate with climate change adaptation such as indicators for soil health and diversity. Or it could be linked to applications of certain practices that in general show good climate change adaptation performance, such as optimized diverse crop rotations, use of organic fertilizers, or agroforestry, to name just a few.

Furthermore, we emphasize the central role of institution related aspects, such as knowledge co-creation and dissemination via advisory services and farmer-to-farmer approaches, etc. to support development, improvement and uptake of agroecological practices. When supporting agroecology and fostering climate resilience, it is thus important to establish and strengthen functional knowledge and innovation systems. This also comprises adequate investments in research and development which is currently hardly targeted for agroecological and related production systems that are chronically underfunded. A key aspect thereby is the need to approach innovation and knowledge transfer in a context-sensitive manner, i.e. that the suitability of an option depends on the context (Sinclair and Coe, 2019). Of particular importance is the question of how to reach out to the broader farm population and bring such "knowledge-intensive" production systems to scale. This is corroborated by the HLPE of the CFS report on agroecology (HLPE, 2019; Biovision, 2020), highlighting that there are fewer investments in research on agroecological approaches when compared to other innovative approaches. In particular, investments are limited in research areas concerning: the economic and social impacts of adopting agroecological approaches; the extent to which agroecological practices increase resilience in the face of climate; relative yields and performance of agroecological practices compared to other alternatives across contexts; and how to link agroecology to public policy (HLPE, 2019).

Another group of important findings from the meta-studies analysed are those on productivity and yields. Agriculture has to ensure food security and this is linked to the ability to provide decent output per hectare. From the meta-analyses we learn that low-input systems, such as organic agriculture, show lower yields than high-input systems. On the other hand, higher diversity tends to correlate with increased productivity and stability. However, single crop yields are not the best measure to assess the productive potential of an agricultural production system. It is more adequate to average production over space and time by using more aggregate measures such as total income or total calories or human-edible protein provided from a certain area over a certain period, or even more encompassing, the "land equivalent ratio" as suggested in HLPE (2019). Such measures are better suited to capture the relevant aspects of productivity, resilience, and adequate nutrient supply in relation to food security.

The assessment of the performance and stability of such more encompassing productivity indicators, in particular in the face of ever more challenging climatic conditions, should become standard when assessing the climate change adaptation potential of agricultural production systems. Furthermore, yields have to be seen in relation to what they are used for and reducing areas cropped to produce feed or output that is then lost or wasted would reduce the pressure to achieve ever-higher yields on given areas. Finally, agriculture is multifunctional and in an encompassing sustainability assessment, yields are only one indicator among many others. Sustainable future food systems depend on agriculture performing optimal on many indicators and not maximal on one and worse on others.

3.4.2 Research gaps

While there is much robust evidence from meta-analyses and reviews, our search did not result in many case studies that provide specific and robust evidence for the relative performance of agroecology with respect to some baseline production systems regarding climate change adaptation and resilience. Thus, the case study-based evidence on agroecology and climate change adaptation with a clear agroecology focus and a reference scenario remains scattered and anecdotic. This is also due to our aim to provide a highly robust scientific knowledge basis for the climate change adaptation performance of agroecology, which resulted in many case studies not being included in our review (only 17 out of 185). There is a huge number of CSOs' testimonials and reports on agroecological case studies available and reporting their good performance, but hardly any of those met our selection criteria for the case study review. Furthermore, in this data, there may be a bias due to the self-declaration of being agroecological and the fact that most agroecological work is still done by institutions that are in favour of this approach. The self-declaration bias is somewhat mitigated by our complementing research based on other keywords than agroecology (**Annex 2.4**). However, we cannot judge on the importance of or control for the bias resulting from institutional inclinations towards agroecology.

A big challenge for the work on agroecology, climate change adaptation and resilience is the need for truly encompassing studies to capture agroecology and for long-term studies to truly assess adaptation. Furthermore, there is a need for much more well-designed comparative studies (Côte, *et al.*, 2019), with optimal sample design, where Bezner Kerr *et al.* (2019) may serve as an example. If done in the context of extreme events such as droughts, hurricanes, etc., such assessments of the relative performance of agroecological versus some baseline farms in the face of these shocks could provide key insights into adaptive capacity and resilience, as they would avoid the challenge of long-term observations to see some signals from adaptation activities. More research of this kind would be needed to be able to assess the adaptation potential of agroecology in its full complexity and to identify which aspects may be most important for successful adaptation.

3.4.3 Submission for Koronivia Joint Work on Agriculture: elements to be included in topics 2(b), 2(c) and 2(d)

Based on the results of this review on the potential of agroecology for climate change adaptation, the authors have submitted inputs to the KJWA. A first submission has been prepared between Biovision and FiBL, targeted at the topics 2(b) "Methods and approaches for assessing adaptation, adaptation co-benefits and resilience", and 2(c) "Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management", for the SBI/SBSTA50 in June 2019. A second submission has been prepared between IFOAM Organics International, IFOAM EU, Biovision and FiBL, targeted at topic 2(d) "Improved nutrient use and manure management towards sustainable and resilient agricultural systems".

3.5 CONCLUSIONS

First, albeit working with proxies, correlations and plausibility arguments, and having made explicit the potential challenges that come with such an approach and the underlying data we used, our results clearly allow to conclude that:

- agroecology builds on key practices and characteristics that are performing well with respect to indicators that strongly correlate with climate change adaptation and resilience, such as various indicators related to soil health and biodiversity, but also productivity and yield stability; and
- furthermore, these key practices and characteristics correlate with indicators for mitigation co-benefits, mainly related to soil organic matter, but also via reduced input use.

Hence, we can argue for an increased support for those practices and characteristics which are central in agroecology, for supporting approaches that build on them, and for more investments in research and implementation of those, as they provide promising alternatives to the currently dominant approaches that come with many known drawbacks.

The results also allow to further refine some findings. An example would be the fact that organic agriculture shows lower yield stability, while increased diversity strongly correlates with more stable production and, therefore, long-term and livelihood resilience. This suggests that organic agriculture may not fully implement and build on its diversity potential and also in this it differs significantly from agroecological approaches. This would be an important area for further research to improve organic agriculture as a well-defined exemplary system that is closely related to agroecology, and also to gain further insights on the relationship between productivity, stability and diversity in agro-ecosystems. Several aspects are also missing in the meta-analysis, e.g. water management and water use, and also the role of seed availability and seed diversity.

Second, the central role of knowledge transfer, co-creation of knowledge, etc. warrants a specific emphasis on this topic. This central role has been recently reemphasized in the HLPE of the CFS report on agroecology (HLPE, 2019), which highlights the key importance of enabling policies and instruments, as well as investments for transition pathways. NGOs and other institutions often play a central role as facilitators of these processes, in particular by providing funding and organizing exchange with relevant institutions. This is clearly illustrated for IPs, for example, where success seems to strongly depend on the presence and type of social capital and the relevance of specific context characteristics for innovation delivery.

CHAPTER 4

CHAPTER

4

COUNTRY CASE STUDIES ON THE POLICY AND TECHNICAL POTENTIAL OF AGROECOLOGY

To further scrutinize the findings from the research meta-analysis, two case studies in Senegal and Kenya were conducted. Both countries have a track record of sustainable agriculture practices which are also currently considered in their climate strategies. For each case study the policy and the technical climate potential was assessed through methods that are explained below.

The goal of the technical potential analysis is to provide a better understanding of the ecological and socio-economic performance of agroecology, based on a rigorous comparative analysis addressing the question: are agro-ecological production systems more resilient than non-agroecological ones? And if so, why?

The goal of the policy potential analysis is to provide a better understanding of the current political context as well as the enabling environment and the obstacles for agroecology to be considered in the decision-making process and out-scaling. The policy potential indicates to what degree the political context (in a country) provides an enabling environment through its polity, policies and politics that fosters awareness, acceptance and implementation support for agroecology approaches.

4.1 OVERALL METHODOLOGY

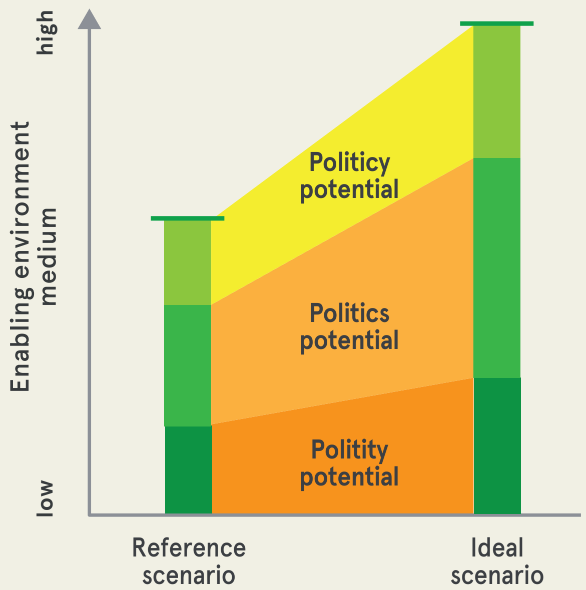
4.1.1 Methodology for assessing the policy potential for agroecology

Research methods and thematic focus

To assess the policy potential, firstly a reference analysis is conducted that reflects what the current overall policy situation is and whether/how agroecology is framed and embodied by such. Secondly, and based on this reference, a hypothetical ideal scenario in 2025 is defined, that describes an enabling environment for agroecology to be politically considered (political awareness), accepted (political will) and effectively fostered (political commitment/action). The difference between these two situations defines the bandwidth of the future policy potential for agroecology. To specify this, finally, a gap analysis between these two settings will identify opportunities and challenges for a transition from the reference to the ideal scenario and thus validate the existing policy potential (see **Figure 16**).

FIGURE 16.

POTENTIAL SCENARIOS DEPENDING ON ENABLING ENVIRONMENT



The assessment of scenarios is based on literature reviews, semi-quantitative word analysis, questionnaire-guided interviews and focus group discussions (FGDs). Through interviews and FDGs multiple aspects of the methodology below can be covered at the same time.

For the reference analysis to adequately assess the current political status of agroecology, and political will for fostering it, the analysis is approached from the following three angles:

- **Polity angle 1:** a literature review is performed to assess the political system, functioning of institutions in charge, existing visions and long-term strategies, priorities and major current programs in agriculture. The conducted focal group discussions are evaluated in terms of the institutions' functionality and the status of visions/long-term strategies when compared to actions in reality. Further, a discussion on the success and sustainability of the implementation of policies and enforcement of regulations is undertaken, along with an assessment of the overall normative framing of agriculture and food system by the government (recognition, expectations).
- **Politics angle 2:** FDGs and key stakeholder interviews were conducted in order to assess the awareness, understanding and acceptance of the agroecology approach among power vested stakeholders engaged in the policy-making process.
- **Policy angle 3:** the degree to which agroecology approaches are already addressed, fostered or hindered through existing or planned policies in the climate change context is assessed.

A literature review and word count analysis is conducted (1) to analyse current key policies related to agriculture, climate change, natural resource management and/or economic development; and (2) to identify and assess policies that don't explicitly mention agroecology but address selected elements of it.

Through semi-structured interviews, we assess what new policies are currently in the making or planned that could have implications for the agriculture sector in the climate context.

Finally, based on the aforementioned approach, a qualitative rating for each assessment angle is conducted that will identify whether an overall low, mid or high enabling political environment exists in the country for agroecology.

To specify what a desired enabling political environment for the agroecology approach would look like in an ideal scenario 2025, the following aspects are addressed in FDGs:

- identify a hypothetical setting within the political system in 2025 that provides a solid bedrock for the agroecology approach in the country;
- characterize and discuss the institutional and normative dimensions of such scenario;
- specify which policy actors would need to take what position and actions to facilitate the development or implementation of policies that would be needed to follow this scenario; and
- describe realistic and lasting policies/regulations that would be needed to allow the accomplishment of this scenario.

4.1.2 Methodology technical potential

The technical potential analysis is done through a two-steps approach:

1. Sampling of smallholder farmers based on partner organisations' assessment. Grouping into "agroecological intervention group" and "control group" (farmers not being part of an agroecological group/movement).
2. Assess the resilience of these farms using SHARP and compare the two groups.

In detail these steps consisted of:

Sampling design

The agroecological system sampling was based on farmer's associations in long-lasting relations with NGOs and community-based organizations (CBOs). These NGOs and CBOs are supporting agroecology and the use of indigenous knowledge systems for food production and provide insight into sustainable agricultural technologies for the management of soils, water, crops, animals and pests. For the case study purposes, the pursuance of sustainable agriculture through these pathways was taken as a representation of "agroecological transition". The sampling approach was based on spatial distribution and randomized sampling of farmers, identifying the "intervention group" of agroecological farmers based on the following criteria:

- farmers who are part of such agroecology projects for at least five years;
- the exposure to climate variability;
- the proximity to control group members (within the same locality – to control the location effect); and
- mixed cropping systems and crop-livestock integration.

Non-agroecological farmers were randomly selected from the same regions ("control group") to closely match the agroecological/climatic conditions, livelihood strategies and landholding patterns of the agroecological producers ("intervention group").

Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralist (SHARP)

The collection of field data in both case studies was carried out through face-to-face interviews using the SHARP tool app version 0.13.18, a structured survey tool for resilience assessments developed by FAO.

SHARP focuses on identifying the areas of vulnerability and strength of the farm systems and agriculture-based households, while building on flexibility, learning and knowledge of farmers (Choptiany *et al.*, 2017). It considers resilience as an intrinsic aspect of the system and farmers themselves.

Consistent with the overall SHARP tool methodology, the collection of data on different farm system components was done in the form of 39 modules, broadly covering four domains, i.e. agronomic practices, environmental aspects, social interactions, economic components and governance. However, the modules on governance and energy conservation practices were omitted in the survey exercise. Furthermore, since the module on general information doesn't result with the scoring, this brought the number of modules used for resilience assessment to a total of 36. These modules are grouped under different domains to which they are applicable.

The SHARP assessment is based on the combination of quantifiable (objective) and qualitative (subjective) questions spanning across the above-mentioned domains. Regarding the objective information, each module was divided into subcomponents defining different aspects of that farm component, e.g. module 22 on trees assessed (i) diversity of tree species; (ii) number of trees; and (iii) use of tree products etc., and each subcomponent was scored independently.

To translate into a resilience measurement tool, SHARP gives each subcomponent a score to identify the resilience levels of the farm systems. SHARP tool automatically generates three scores for each module: technical (objective), adequacy and importance score (subjective). The scores for the objective component (i.e. technical scores) are grounded on academic and expert knowledge and they range from zero for low resilience to ten for high resilience. The subjective information (self-assessed adequacy and importance) is based on the perceived and expressed needs of farmers aimed to capture the perceptions of farmers regarding the adequacy/sufficiency levels of a given farm component or resource, as well as the priority of given elements in the farms. Both are measured through a Likert scale: the self-assessed adequacy score ranges from zero to ten, with ten corresponding to high adequacy, while the score for the self-assessed importance is an inverse scale ranging from ten to zero, where zero is a self-reported high priority/importance.

The aggregate of the subcomponent scores, as described above, resulted in the technical score for each module, which provides an objective estimation of the resilience of the farm system.

Only considering the technical scores, the SHARP modules are compiled into sub-indicators and are aggregated in a manner that the 13 agroecosystem resilience indicators can be measured as defined by Cabell and Oelofse (2012). **Table 1** below shows how the technical score of different sub-indicators is translated into resilience scores for different indicators of resilience.

TABLE 1.

AN EXTRACT OF SHARP SCORING AGROECOSYSTEM RESILIENCE INDICATORS BASED ON MODULES AND SUB-INDICATORS

SHARP AGROECOSYSTEM RESILIENCE INDICATOR	SHARP SUB-INDICATORS	SHARP MODULE THEME	SHARP MODULE SUB-COMPONENTS (QUESTIONS)
1. *Socially self-organized*	1.1 Group membership	36. Group membership	36. Participation level
			36. Initiation of the group
	1.2 Access to local farmer's markets	30. Access to markets	30. Sell of produce in local markets/ cooperatives/associations
			30. Access to information on market prices
	1.3 Previous collective action	35. Community cooperation	35. Joint problem solving by community members
			35. Mechanisms in place for problem-solving
	1.4 Access to communal resources	5. Land access	5. Area of communal land accessible
	1.5 Financial support	33. Access to financial services	33. Financial support received when needed
5. *Optimally redundant*	5.1 Varietal diversity	13. Animal production	13. Number of breeds
		6. Crop production	6. Number of crop species

*Resilience indicator score (*socially self-organized*) is an aggregate of sub-indicator scores (1.1 group membership, 1.2 access to local farmer's markets etc.). The sub-indicator scores are obtained from the SHARP module subcomponents. Alike sub-indicator, 5.1 (Varietal Diversity) is an aggregate score obtained from both the animal and crop production module.*

In this study, the 13 agroecosystem indicator scores were based on 92 sub-indicator scores. The sub-indicator score was assessed from the subcomponent (question) scores of the modules as shown in **Table 1**. For example, socially self-organized indicator assesses the farmer's ability to organize into grassroots networks and institutions such as cooperation's and farmers' markets. Therefore, the final score will be an aggregate sum of scores from sub-indicators of 1.1) group membership, 1.2) access to local farmers' markets etc. derived from the sub-components of group membership and access to market modules respectively (**Table 1**).

In some instances, the sub-indicator was assessed through scores of subcomponents from multiple modules. For example, the sub-indicator score for varietal diversity was dependant on two subcomponents: the number of animal breeds reared (from animal breeding practices module) and the number of crop varieties cultivated (from crop production module). The final scores were standardized on a scale of 0-100 percent, classified as low-level (0-35 percent), mid-level (36-70 percent) or high-level (71-100 percent) resilience.

Aside from providing resilience scores, the module scores were used to identify areas of priority intervention based on the summation of technical, adequacy and importance scores. This means that interventions scoring low on the technical and adequacy score and high on the importance would be those with lowest total scores and thus highest priorities by the farmers. Therefore, the lowest scores were considered to be areas of high priority.

A two-tailed sample t-test was used to assess differences for SHARP scores between agroecological and non-agroecological at the agroecosystem resilience indicator level (1. *Socially self-organized*, 2. Ecologically self-regulated etc.), the sub-indicator level (1.1 Group membership, 1.2 Access to local farmer markets, etc.), module-level (2. Households, 3. Production activities, 4. Non-farm income-generating activities, etc.) and at the domain-level (Agronomic practices, Environmental aspects, Social interactions and Economic components) (**Table 1**).

Prior to applying the t-test, suitability of the dataset was assessed for normality (using Shapiro-Wilk normality test) and homogeneity of variance (Levene Statistic). For non-normal distribution datasets, a non-parametric test (Wilcoxon rank sum test) was applied. For non-homogeneity of variance, a Welch two-sample t-test was applied. All tests were performed in R version 3.6.1.

4.2 RESULTS CASE STUDY KENYA

4.2.1 Context Kenya

Climate risks pose serious threats to Kenya's sustainable development goals. With the largest economy in East Africa and a population of 48.5 million, Kenya serves as the region's financial, trade and communications hub. The country's economy is largely dependent on agriculture, and particularly on its susceptibility to climate variability, climate change and extreme weather events. Increasing inter-seasonal variability and declining rainfall in the main rainy season have impacted cereal production in recent years. Recurrent droughts and floods — likely to be exacerbated by increasing temperatures, heavy rainfall events and sea-level rise — lead to severe crop and livestock losses, famine and displacement. The 2008-2011 drought caused $12.1 billion in losses and damage. As Kenya is deficient in its major staple crops and therefore has to import a substantial amount of food, further climate change perturbations will only increase this dependency. Models estimate that by 2030 climate variability and extremes will lead to losses equivalent to 2.6 percent of GDP annually (USAID, 2018).

Despite the importance of agriculture in Kenya, the sector does not receive high priority in terms of budget allocation compared to other sectors such as infrastructure and energy. This is reflected in lower agricultural growth and therefore, a framework or strategy for climate change adaptation and mitigation is required within which there is increased investments in agriculture, supportive policy and use of climate-resilient technologies appropriate to mixed farming conditions involving crops and animals.

4.2.2 Policy potential in Kenya

Policy setting in Kenya

Transforming agriculture productivity to deliver on food security and nutrition, build resilience to the impacts of climate change, eliminate social inequality and minimizing biodiversity loss is at the heart of Kenya's Big Four Agenda, the national climate change response strategy and other economic and social development strategies. This recognition is embodied in various policies that aim to transition Kenya into a sustainable food and agriculture system. Through the implementation of the Big Four Agenda, Kenya aims to reduce the number of food-insecure people by 50 percent and achieve a 27 percent reduction in malnutrition among children under the age of five years (MALF, 2017).

Kenya's vision for 2030 and the implementation of the Big Four Agenda aims to move its economy away from over-reliance on agriculture by transforming itself into a hi-tech service hub that will generate innovative and entrepreneurial potentials. Despite that, Kenya has developed and is implementing several agricultural and climate change policies aimed at increasing food security and nutrition. The overarching goal of the agricultural sector in Kenya is to contribute to improvements in food and nutrition security and income generation through the promotion of improved management of natural resources and practices compatible with sustainable and climate-resilient agricultural production (GoK, 2018a). On the other hand, the goals of climate change policies and strategies are to enhance adaptive capacity and resilience while promoting low carbon development.

To address extreme weather events, the government developed and is implementing numerous agriculture and climate change-related policies and strategies. One of these policy frameworks is the Kenya Climate Smart Agriculture Strategy (KCSAS) developed in 2017 and complemented by the CSA Implementation Framework in 2018 that was developed through a multi-stakeholder process. The two documents have identified challenges and opportunities for CSA to hedge against climate impacts in the agriculture sector in Kenya (GoK, 2017; GoK, 2018a). However, there is a feeling that the concept of CSA could be inclusive of "business as usual" approaches to agriculture.

Kenya's agricultural policy environment is influenced by the political economy of agriculture that is influenced by the country political system which generates the policy incentives to promote agricultural development and/or private sector and donor interests. The existing agricultural policies are seldom farmer or community-driven and thus often do not respond to the local needs.

Given these deficits, there is a need to leverage more specific approaches on the agenda of decision-makers to facilitate the upscaling of good agricultural practices. One promising entry point is identified in systemic approaches that build on agroecological practices in the agriculture sector or through the incorporation of these practices in the CSA narrative, as it is well established in Kenya. However, despite the evidenced positive effects of systemic ecological measures to combat climate change, numerous pilot-projects often portray these measures as singular and small-scale interventions with limited opportunities to go to scale (Wankuru *et al.*, 2019; Wigboldus *et al.*, 2016). Factors limiting scaling up and out of agroecological approaches include low awareness about the potential of these approaches. Others relate to the knowledge-intensive nature of agroecology, its context-specificity and absence of supporting political frameworks, and technical or economical barriers such as initial or transaction costs.

Research approach

Building on the above-described context in Kenya, this case study aims to explore the policy potential of agroecology in Kenya, specifically to assess how the current agriculture and climate change-related policies and strategies can support the uptake and upscale of agroecology (see **Chapter 4.1**).

This case study used qualitative research methods, including literature review, semi-structured interviews and FGDs. During the literature review, a number of government policies, strategy and implementation documents were reviewed with an agroecology lens, specifically identifying agroecology elements and practices (**Annex 2**). For this study, we searched for agroecological elements such as resilience, efficiency, diversity, biodiversity, synergies, co-creation and sharing of knowledge, recycling and responsible governance in policies and strategies (Wezel *et al.*, 2014). An analytical assessment of current agriculture, climate change and other related policies and strategies was undertaken to provide an overview on how much and how far agroecology is embedded within them. We analysed policies related to agriculture, climate change, forestry and water. In the absence of a national policy specifically on agroecology, agroecology elements could be embedded in such existing related policies at least.

Twenty-one policies and strategies related to agriculture, environment, water and forestry from the past 20 years were reviewed (**Annex 2**). An integrated two-step analytical framework, focused on policy content, was adopted. Step one and two involved an analysis of agroecology elements and practices, respectively. The elements and practices are drawn from FAO (**Annex 2**) that can be applied across ecological, economic and social-cultural environments.

Semi-structured interviews were conducted with fourteen participants from various organizations that are active in the agriculture sector. These are government institutions, policymakers, CSOs, NGOs, and national research organizations. The interviews focused on exploring the understanding of agroecology by stakeholders and the current political situation with regards to agroecology. We further assessed whether and how agroecology and its elements are currently considered within agriculture, environment, water, and forestry policies.

In addition, two FGDs were held. The first FGD comprised government officials from different sectors and departments. The second one comprised CSO and NGO representatives. Some of the issues discussed during the FGD included how agroecology is embedded in the agriculture discourse in Kenya, what current policies are related to agroecology and what is needed to support agroecology approaches and initiatives in Kenya.

Results and analysis

POLICY ANGLE: ANALYSIS OF POLICIES IN KENYA

The analysis revealed that no policy specifically related to agroecology exists within the current national agriculture and climate change policy arena, even though there are some closely related frameworks such as the KCSAS. Nonetheless, devolution has provided a chance for counties to develop policies based on the prevailing circumstances and a county like Kiambu already adopted a law on agroecology as the first one among the 47 counties. This seems to have had an influence on other counties, as in Meru interventions aimed at promoting agroecology are currently being elaborated (Osumba, forthcoming).

Agroecology elements in existing policies in Kenya

The review of Kenya policies indicates that, despite the absence of the word "agroecology", there is a consideration of agroecology elements and practices aiming at increasing agricultural productivity and building resilience. Most of the policies mention or infer on two to three out of the ten FAO agroecology elements. However, the elements referring to culture and food traditions, and circular and solidarity economy are not mentioned nor inferred.

With regards to the agroecology elements mentioned in these policies, their goal is to improve food security and nutrition, building resilience (FAO agroecology element) of Kenya's agricultural systems and, enhance the adaptive capacity of farmers. For example, Kenya's NDC's emphasis is on increasing resilience of food systems and enhancing adaptive capacity through enhanced coordination of climate change action, public participation and inclusiveness (implying the FAO elements related to human and social values as well as responsible governance). According to the NDC, building resilience implies improving efficiency (FAO agroecology element) of resource use in all agricultural production systems (including supporting sectors such as water and energy) as well as the implementation of policies that will lower costs of production, hence increasing productivity. The FAO agroecology element on diversity is mentioned in terms of increasing crop, livestock, plant and soil biodiversity, which is threatened by the changing climate and related effects such as pests and diseases.

BOX 2: EXAMPLE OF AN EXISTING POLICY REFERRING TO AGROECOLOGY ELEMENTS

The national KCSAS and CSA Implementation Framework outline climate-resilient agricultural elements and institutional arrangements to circumvent climate impacts in the agriculture sector. Some elements of agroecology do overlap or diverge with the CSA strategy and implementation framework. Of the ten agroecology elements, **resilience, efficiency, diversity and synergies** are clearly articulated in the strategy and framework. Other elements such as **culture and food traditions, co-creation and sharing of knowledge, recycling and responsible governance** can be inferred. However, elements of **human and social values and circular and solidarity economy** as an impetus for transformative agroecology that can lead to food security and sovereignty are not considered.

Identifying and **reinforcing synergies** between objectives of food security, poverty reduction, adaptation and mitigation actions in the agricultural sector is another FAO agroecology element considered within the policies. The policies will also integrate cross-sectoral approaches to enhance synergies and promote efficiency within implementing institutions and stakeholder. Agroforestry is one of the agroecology practices highlighted and seen as having the potential to provide this synergy and to offer resilience benefits and reduce emissions in agricultural systems (GoK, 2018a).

> **"The Agricultural Sector Development Strategy (ASDS) recognizes Kenya's agro-ecological diversity and aims to improve *diversity* of food to meet dietary and nutritional requirements, increase agro-biodiversity to include traditional sources of food and support use of organic methods for *sustainable* food production systems" (MoALF, 2018).**

Despite not clearly mentioning co-creation and sharing of knowledge in the policies, stakeholders, including farmers, will be involved in communication, awareness, education, advocacy, public participation, public access to information on priority climate-resilient crops and livestock and, adaptation actions in the agriculture sector such as water conservation and recycling, indigenous knowledge, efficient use of water and energy, early warning systems and agroforestry (GoK, 2017; GoK, 2018).

Governance frameworks based on the elements of accountability, transparency, rule of law and participation are applicable at the national level and will be cascaded down to county levels and provide a clear system on what is expected to be done at each stage. However, what is missing within the policies is the presence of good governance mechanisms such as equity, inclusiveness, community and traditional level governance that can support different actors to transform their practices to be climate-resilient and sustainable, while maximizing synergies along agricultural value chains.

Finally, the agroecology element associated with recycling is not directly mentioned in the policies except in the water sector, whereby public awareness on water conservation and recycling is indicated as an efficient water use practice. Accordingly, there is potential to further streamline this element in other policies.

Agroecology elements in climate-specific policies in Kenya

Agroecology is indirectly addressed in selected climate change policies and strategies in Kenya. Kenya passed the Climate Change Act (2016) which provides a regulatory framework to guide national and county governments in the response actions addressing climate risks and strengthening climate resilience in the country. The Act provides an elaborate mechanism to guide the mainstreaming of climate change into sectoral policies, including monitoring and implementation. The National Climate Change Response Strategy (NCCRS) (GoK, 2010a) is the framework that guides the integration of climate concerns into development priorities. The NCCRS is translated into National Climate Change Action Plans (NCCAP) through the Climate Change Act of 2016. Implementation of the Climate Change Act is through the National Climate Change Action Plan (NCCAP) 2018-2022.

SLM is among the climate actions proposed in the NCCAP. The specific activities planned under SLM reflect certain agroecology elements and practices, such as integrated soil-crop-water management, agroforestry and agro-silvopastoral systems; managing soil organic matter for soil carbon sequestration; preventing and mitigating land degradation and restoring degraded soils and lands (GoK, 2018b).

In addition, the agricultural sector developed KCSAS 2017-2026 with the objectives of adapting to climate change, building resilience of agricultural systems while minimizing emissions for enhanced food and nutritional security and improved livelihoods (GoK, 2017). KCSAS outlined some of the climate change-related issues farmers are facing in Kenya, including unsustainable agricultural land management practices, inefficient crop and livestock production systems, the use of fossil fuel in the agriculture sector, as well as poor management of fertilizers, manures and agricultural wastes. To implement the KCSAS and provide guidance in mainstreaming CSA, the CSA Implementation Framework (KCSAIF) 2018-2027 was developed. In this framework, agroecology is not explicitly referred to but some of its elements are indirectly implied. This includes diversified and improved crop varieties (high yielding, short duration, disease and pest tolerant, high nutritive value, flood-tolerant), the use of integrated soil fertility management practices, and promoting indigenous and locally adapted breeds and varieties.

Agroecology practices in Kenyan policies

The key policies reviewed are to some extent consistent with agroecology elements and practices of achieving a balanced and sustainable agricultural system within socio-economic, ecological, political and environmental spheres. While the Kenyan government has promised a policy and institutional environment that is conducive to increasing agricultural productivity and resilience, the agricultural landscape is heavily penetrated and controlled by input supply agribusinesses (GoK, 2010b). This has created uniformity across farming landscapes, exposing crops and livestock to emerging pests and diseases.

Most of the policies and strategies propose to increase finances for external inputs and create awareness campaigns for their use. For example, the ASDS aims to bulk purchase and supply external inputs for smallholder farmers. This is in contrast to agroecology, which encourages the use of integrated and traditional soil fertility, disease and pest management practices that enhances farm, crop and livestock diversity and harnesses resulting synergies.

The CSA strategy and framework selectively incorporated some agroecological practices and combined them with adaptive, traditional and environmentally sustainable technologies such as the provision of weather and agro-advisory information along value chains for decision-making and insurance, efficient water use including irrigation and, conservation and propagation of adaptive crop and livestock germplasm. Some of the CSA and agroecology practices that overlap include: integrated pest management that minimizes the use of pesticides on emerging pests and pathogens brought by temperature rises; agroforestry to bridge agricultural development and forest protection; and integrated soil fertility management.

Nonetheless, also agroecology-related practices are identified few and far between policy documents, which refer for instance to conservation agriculture, agroforestry, SLM, cultivation of drought-tolerant indigenous crops, water harvesting, livestock management and integrated soil fertility management. Overall, almost all agriculture-related policies consider increasing crop-, livestock-, fishery- and soil-diversity to enhance ecosystem services and the sustainable use of resources, as key for adapting, mitigating and building resilience to climate change.

Agroforestry is most the popular agroecological practice mentioned in most documents to increase tree cover in farmland, improve nutrition and incomes, preserve and maintain the environment and, enhance carbon stocks.

Reasons for the lack of agroecology policy in Kenya

During interviews and focus group discussions, various reasons were outlined by the respondents for the lack of agroecology policy in Kenya. These include:

- **Food security is the current priority for the government.** It aims at maximizing yields for economic benefit as well as for providing enough food for the population. The focus is on production and integrated food system perspective is mostly missing. Agroecology is perceived as being applicable only on small scales, which the government sees as a limitation for meeting its objectives. CSA is thus seen as a more viable option towards achieving food security for the country.
- **Agroecology is not well-known.** Agroecology is a relatively recent concept in Kenya and its elements have not yet been well understood among the policymakers. Hence, there is a need to invest more in research and sensitization so that its benefits can be well understood amongst stakeholders.
- **There is a multiplicity of terms and concepts.** Agroecology practices are being employed by farmers throughout the country even though they call it differently. If the government opts to develop strategies for every new approach that comes up, then there will be thousands of strategies which will be, not only confusing, but also difficult to implement.
- **In Kenya, the distinction between CSA and agroecology is not clear.** For those who are somewhat familiar with agroecology, they consider it part of CSA with a lot of synergies between the two concepts. The elements underlying agroecology and CSA have to be contextualized until the overlaps between the two are clearly defined.
- **There are powerful conflicts of interest.** If Kenya were to promote agroecology, there would be conflicting interests by policy makers that have vested interests in conventional agriculture or by profiteers of other opposing policies.

The lack of understanding of agroecology amongst policymakers may be the greatest barrier to its inclusion in climate change policies and strategies. As one interviewee puts it:

> **"Agroecology has a space in climate policy dialogues, but very few people who design policies know or even understand it. Additionally, agroecology is not being discussed or advocated for like climate change. No one is talking about it, no one is teaching the policy makers about it and information is not being shared. The perception is that if they are aware of the practice and understand how it works, then it might be an issue for discussion but this, however, may take a long time".**

POLITICS ANGLE: ANALYSIS OF THE POLITICS SETTING IN KENYA

This section analyses the role, awareness, understanding and acceptance of the agroecology approach among key stakeholders engaged in the policy-making process. We assessed whether they understand the agroecology approach and how it differs from other concepts, whether they accept it as a valuable approach and whether they would be willing to support and promote it in their policy work.

Actors involved in agriculture and related policy-making and implementation process in Kenya

During FGDs, the main actors (state and non-state) in agriculture and climate-related policy-making and implementation were identified. The major state actor identified was the Ministry of Agriculture, Livestock and Fisheries (MOALF), specifically the policy directorate. In some cases, the engineering department within the MOALF can initiate a policy development. County governments are also expected to identify policy gaps and implement policies at the county level.

Non-state actors identified were donor organizations, international non-governmental organizations (INGOs), national non-governmental organizations (NNGOs), universities, research institutes, development partners, private sector and CSOs. Non-state actors such as donors and INGOs contribute through policy gap identification, funding, and providing scientific evidence to the development of policies. CSOs and NNGOs are usually involved in the development and validation of the policies and lobbying policymakers to support policy proposals.

TABLE 2.

ACTORS ENGAGED IN THE KENYA POLICY-MAKING PROCESS AND THEIR ROLES

ACTORS	ROLES
STATE ACTORS	
Policy Directorate and Engineering Dept. at MOALF	• Identify policy gaps • Main actor to develop policies
County Government	• Identify policy gaps • Once a policy has been developed, domesticate the policy to suit their context • Implement policies
Members of Parliament	• Pass or reject the policy
NON-STATE ACTORS	
Donor Organization	• Provide funding for policy development and/or implementation • Provide technical expertise
INGOs	• Provide funding for policy development and/or implementation • Provide scientific evidence to identify the extent and nature of the problem that the policy will address • Provide technical expertise
Universities and research institutes	• Provide scientific evidence to identify the extent and nature of the problem that the policy will address • Provide technical expertise
CSOs	• Involved in policy validation processes • Lobbying with policy makers • Summarizing the policy into a text that is easily understood by farmers and consumers • Policy implementation at grassroot level • Policy gap identification
Private sector	• Policy gap identification • Funding for policy development
Farmer organizations*	• Policy development and implementation

** Kenya small scale farmers' federation (KEFF); Kenya national farmer federation; Kenya Agricultural Industrial networks; Kenya Dairy Board*

Notwithstanding the generalities outlined in **Table 2**, the specific roles and agendas of different actors are highly dependent on the policy being developed. Further, two insights that were given by FGD participants are particularly noteworthy:

> **"Kenya lacks a strong consumer movement that can participate in agriculture policy design and implementation."**

and

> **"The policy directorate in the Ministry of Agriculture does a lot of moderation in policy development. They do not want every actor to start proposing policy development."**

Overall perception of agroecology among stakeholders

The interviews and FGDs revealed that agroecology is an ill-defined and seldom used term among stakeholders in Kenya. Frequently, it is interchangeably used with CSA. For many actors there is not a clear line that sets agroecology apart from CSA. On the other hand, the perception prevails that agroecological practices are commonly used by Kenyan farmers, although mostly under different umbrella terms. Only stakeholders who are directly involved in promoting agroecology (mostly CSOs) are able to define what it entails and clearly distinguish it from CSA.

For most of these stakeholders, agroecology is seen as a holistic farming process that involves a number of practices such as integrated soil and water management, crop diversification; use of natural processes and inputs in crop and livestock production; and that emphasises sustainability, biodiversity and human health. It is considered an approach that can help communities adapt to the effects of climate change while building their resilience, hence a means of feeding the population especially at a time of changing weather patterns.

Most of the respondents felt that agroecology still needs to be researched on in terms of its potential benefits, unpacked in a way that will be clearly understood and the practices well explained before thinking of developing a policy; and even then, not all of them agreed there is need to have an agroecology policy. There is a diversity of opinion among the stakeholders in terms of accepting agroecological approaches for food production in Kenya. One government official pointed out:

> **"The ministry supports technologies that give farmers food, we do not have a blanket that this (agroecology) is the only thing to support. We support strategies which ensures farmers grow food and as much we would support agroecology, we still have to support the usage of conventional fertilizers for maximum yield."**

A CSO representative, on the other hand, reiterated that:

> **"Agroecology is probably the only option to address climate change as it is a holistic approach to ecosystem protection".**

The general agreement is that indeed climate change is making it impossible to grow food under the 'business as usual' scenario and therefore climate-smart strategies should be incorporated. This will ensure that farmers are able to produce food which can feed the population, but at the same time caution should be taken to ensure that biodiversity is not hampered since it supports the functioning of agroecosystems which include adaptation to climate change.

Perception of agroecology in the context of climate change

Osumba (forthcoming) states that there is a high potential for CSA policies to support systemic and sustainable agriculture, including agroecology. This conclusion is supported by the stakeholders who participated in the interviews and FGDs, concurring that agroecology has a space in climate change policy dialogues. However, their perception is that addressing climate change in the agricultural sector does not have a single solution to it. It needs a number of strategies and agroecology is one of them. According to one interviewee:

> **"Some of the agroecology practices are already practised by farmers such as crop rotation, soil and water conservation, among others, to fight the effects of climate change. While it is not a new concept, it is still not being discussed during climate change meetings."**

Changing the mindset of Kenyan farmers and other stakeholders to embrace agroecology in the face of the changing climate might be difficult. According to another interview partner:

> **"Kenyans, including farmers and policymakers, don't like to change easily and so they are stuck at what they know. Therefore, introducing agroecology to Kenyans implies to change their mindset so that they are not only thinking about chemicals and new seeds, but they see things from a different perspective."**

Increasing awareness on the potential of agroecology might change the perceptions of the wider population. Devolution of agricultural policy processes is a positive aspect in this case since each county can be engaged in promoting agroecology elements and practices. Furthermore, the county government can develop their own agroecology policies or strategies that are embedded within or linked to climate change policies and use them to influence the national government. Unfortunately, this might take a long time to implement as one respondent stated:

> **"The mindset of policy-making people at the national level is focused only on what they learned in college years ago and new ideas such as agroecology are not easily embraced. Additionally, a lot of funding/scholarships in agriculture are funded by donors who have an interest in something they want to promote (e.g. genetic modifications, etc.) and hence trying to change the mindset of people trained in such a system is hard"**

According to another respondent,

> **"Agroecology has a great potential to be included in climate dialogues because agroecology pushes for sustainable agriculture which considers the economic, ecological and social aspects of agriculture, important elements to consider when developing strategies for climate change mitigation. However, the challenge of agroecology is that of quantification. One critical question to ask is, what are the benefits vs losses when practicing agroecology? Agroecology should be unpacked in terms of what are the special practices which then need to be quantified. In climate change cycles, one should be able to report, that practicing agroecology to mitigate against climate change, it reduced X amount of GHG emissions, or it makes farmers more resilient by X percent etc. Unfortunately, what is currently being done is simply the promotion of agroecology without hard data to back its contribution to mitigation against climate change".**

Finally, another respondent mentioned that:

> **"Agroecology has space in climate change dialogues, but it should not be the main agenda. There can be an agricultural/climate change policy in place and agroecology to be part of one of the approaches towards mitigating impacts of climate change. For example, CSA strategy can be amended to adopt agroecology."**

POLITY ANGLE: INSTITUTIONAL FRAMEWORK AND COORDINATION MECHANISM IN KENYA

Policy formulation and implementation in Kenya

Kenya's constitution of 2010 introduced the devolved system of governance, with the main aim to bring services closer to the people. The devolved system introduced two levels of governance, the national and the county governments. One of the services to be devolved is agriculture and various county governments have put forth efforts and programs geared towards the improvement of agriculture. The county governments are equally expected to be involved in agricultural policy development. However, despite agriculture being devolved from the national government, the MOALF at the national level is still playing a key role in identifying policy gaps and initiating policy development. Within the MOALF, the Policy Directorate (PD) identifies policy gaps and develops policies, without involving the county governments. Other stakeholders at the national level can also identify a policy gap and spearhead the development of a policy. As one participant of a FGD puts it:

> **"Development partners including donor organizations can identify a policy gap and engage the Ministry of Agriculture in the development of the policy. Since such policies are not country-driven, implementation is usually a problem. This has led to several policies being written and shelved."**

During policy gap identification, the PD at the MOALF has to address the following questions: What is the nature and magnitude of the problem? What groups in the population suffer from the identified problem? How did the problem come about and why does it continue? What are the immediate and underlying causes? What should be done about the problem? (KIPPRA, 2015).

The ability to successfully implement agricultural policies requires a keen knowledge of the policy implementation plan in order to trigger change amongst farmers and other affected stakeholders, such as consumers. However, in Kenya, the policy makers who are at the national level are often removed from implementing institutions. Policy implementation is under the jurisdiction of county governments. Once a policy has been developed, it is devolved down to counties, who might alter it to suit their county context. CSOs are also expected to implement the policies at a local level, as highlighted by an FGD participant:

> **"The work of the government is to develop policy and its implementation framework. However, the actual implementation is left to the other players on the ground such as CSOs, farmers' organizations, development organizations etc."**

Options for stakeholders to render the agroecology ideal scenario reality

From the focus group visioning exercise, multiple entry points for mainstreaming agroecology in Kenya have been identified and their number might increase as policymakers, farmers, and other stakeholders become more aware of the opportunities and potentials that agroecology provides in the face of climate change. In order for agroecology to reach its full potential, there are several issues that the various stakeholders can address to achieve the ideal institutional setting as outlined in the previous section:

- **Review existing agricultural policies and develop guidelines on agroecology.** This can be done by government officials in conjunction with CSOs and NGOs.
- **Working with local communities and farmer groups** to promote the concept of agroecology and setting up demo-farms for farmers to learn and share knowledge.
- **Capacity building and awareness-raising** for farmers, government officials, CSOs, consumers and private sector entrepreneurs.
- **Conduct research and provide evidence** to show that agroecology can contribute to increasing food security.
- **Introduce agroecology in school curricula.**
- **Train agricultural extension workers** and other agro-advisory service providers on agroecology.
- **Provide incentives for private sector stakeholders to invest in agroecology.**
- **Labelling agroecology products and promoted in the markets.** Additionally, create demand for agroecology products - working closely with the media to market agroecology products.
- **Promote diverse diets**, this will ensure more crop varieties will be grown. Kenyans should be encouraged to explore other varieties of food in order to improve their nutrition and increase the demand for other crops varieties.
- **Influence donor and development partners** to set it as an agenda so that the government can easily adapt it.
- **Encourage agroecology as a social and political movement:** bring people on board to help convince profiteers of the conventional systems, e.g. fertilizer and seed industries.
- **Piloting and testing of agroecology practices** in different agro-ecological zones and culturally diverse communities in Kenya. The country has diverse climatic conditions that can support different agroecology practices. The potential for each area should be identified, tested and promoted for maximum efficiency rather than engaging in uniform farming activities, which are not sustainable for some areas.
- **Unpack and explain agroecology** so that farmers and diverse stakeholders can understand it. Farmers do not get excited about terminologies. They need simple practices that they can easily use on their farms.

Table 3 summarizes some key results of the analysis of the policy potential for agroecology in Kenya, along with its challenges and opportunities that characterize the design and implementation of agroecology policies and strategies aimed at coping with climate change.

TABLE 3.

SUMMARY: POLICY POTENTIAL OF AGROECOLOGY IN KENYA

CHALLENGES	OPPORTUNITIES PUT FORWARD BY RESPONDENTS
CAPACITIES AND KNOWLEDGE	
• Lack of capacity at the national level to develop appropriate/ country-specific agroecological policies and at the county level to domesticate such policies. • Knowledge of agroecology in relation to climate change is a major obstacle. • Major stakeholders lack of knowledge on definitions and concepts of agroecology. • There can be limited staff capacity at county level to implement agroecology.	• Integrating agroecology into CSA strategy and implementation plan. • Build capacities at national and county levels on agroecology underlying its importance in building resilience. • Engage civil society and academic institutions knowledgeable about agroecology and climate change action to help sensitize on agroecology. • Development of agroecology curricula.

PRIORITIZATION OF AGROECOLOGY	
• The prioritizing of agroecology is non-existent at the national level. • A lack of knowledge among policymakers at national level with regard to the importance of agroecology in addressing climate change in the agriculture sector.	• Provide evidence-based examples and case studies on why agroecology is important in addressing climate change. • Communicate the evidence carefully to policymakers explaining why agroecology is important for building resilience. • Demystify 'agroecology' – using advocacy strategies, highlight the practices and benefits of agroecology for farmers.
INSTITUTIONAL STRUCTURES AND PLATFORMS TO SUPPORT AGROECOLOGY	
• Currently, there are no institutional structures or platforms for supporting agroecology. • Since CSA strategy and implementation plan are in place, an introduction of agroecology might create confusion. • Including the private sector and working with non-state actors in agroecology can be an issue. • Weak monitoring and evaluation system of policies; therefore, if an agroecology policy is developed, it may be shelved and never implemented. • Agroecology has not been promoted/incentivized to a point where it can be adopted at a large scale.	• Sensitization on agroecology is needed so that stakeholders, especially farmers, are aware of agroecology. • Engage CSOs and other non-state actors in advocating for agroecology. • Mobilize or engage the private sector involved in agriculture within agroecology dialogues. • Start advocacy and alliances at county level especially counties that are already accepting agroecology and then cascade from there to other counties. • Embed agroecology in existing policies that already have implementation strategies.
FINANCIAL AND TIME RESOURCES	
• It is too costly and there is a lack of resources to develop and implement a policy in Kenya. • Time-consuming: the process involved in designing an agroecology policy will be long.	• Embed agroecology policy within existing policy or strategy such as KCSA and KCSAIF. • Use a pilot county such as Kiambu where agroecology policy is already understood to showcase what can be done with limited resources.

Overall political potential: conclusion and recommendations

Climate change is becoming a critical concern in Kenya since it is deterring development efforts, especially in the agricultural sector. Societal awareness of and political will to address the impacts of climate change are growing and as a consequence, there is an increasing potential for systemic alternatives to conventional agriculture.

This study reveals several insights on the policy potential of agroecology in Kenya and describes existing opportunities and challenges to institutionalizing agroecology.

It is clear from the literature review, semi-structured interviews and FDGs that the concept of agroecology is not yet clearly understood by stakeholders, including government officials, policymakers, CSOs, NGOs and private sector actors. Even most stakeholders that are somewhat aware of agroecology have not embraced it as an agricultural practice that can contribute to food security and build resilience to climate change in Kenya.

Nonetheless, government officials recommend mainstreaming agroecology within existing policies and strategies such as the KCSAS and its accompanying implementation strategy and the new agricultural policy. They also propose providing subsidies and incentives to support farmers to invest in agroecology practices. Private sector actors are usually not willing to invest in organic agricultural practices such as mass production of organic fertilizers and pesticides, and the government does not have incentives to entice them. Furthermore, according to government officials who have an understating of agroecology, farmers may not embrace agroecology, as it is labour and resource-intensive. These two constraints can be addressed by providing subsidies and incentives to encourage farmers to adopt agroecology practices.

The current agricultural and related policies will not contribute to sustainable food systems that enhance community and socio-ecological resilience to climate change. Additionally, the current Kenya CSA and other agricultural policies are not well suited in terms of achieving transformative visions of agroecology that are supported by fundamental principles of human and social values and promote circular and solidarity economy.

Engaging multiple stakeholders that have an interest in agriculture can help to improve the understanding and adoption of agroecology. Of fundamental importance is an improved evidence base for informing policy-makers of the potential of agroecology to contribute to food security and nutrition as well as climate change strategies at national and county level. The key steps and entry points for mainstreaming agroecology are:

- Alignment and coherence of policy processes related to agriculture and climate change towards agroecology elements and practices.

- As Kenya is currently formulating its agriculture policy, this presents a great opportunity to re-evaluate the policy to ensure that agroecology is included.
- Develop agroecology guidelines to guide and inform different stakeholders, especially policymakers. This can also include capacity building, awareness creation and sensitization for all stakeholders on agroecology.
- Provide scientific evidence that shows that agroecology can contribute to increasing food security and nutrition in Kenya and share this evidence with policy-makers.

For the longer term, the following programmatic activities are recommended to ensure a sustained embedding of agroecology elements in Kenya:

- Development of an agroecology strategy and implementation plan that is anchored to an existing agricultural policy. Currently, Kenya is drafting its agricultural policy 2019 which is an opportunity for such. Agroecology can also be mainstreamed into the existing CSA strategy and implementation mechanisms that are being promoted across the country.
- Use the devolved county system to integrate agroecology practices. Some of the counties, for example Meru, Kiambu, Kitui, Embu and Tharaka Nithi counties are already receptive of agroecology.
- Further opportunities exist in education curricula, including agroecology, by supporting farmer organizations that can foster adoption of agroecology practices, and training of agricultural extension workers on agroecology.

4.2.3 Technical potential in Kenya

Methodology

DEFINING AGROECOLOGICAL SYSTEMS FOR THE KENYAN CONTEXT

Two institutions, Sustainable Income Generating Investment Group (SINGI) and The Institute for Culture and Ecology (ICE), were noted to support farmer groups in the adoption of sustainable agriculture practices in Western (Busia county) and Eastern (Meru & Tharaka-Nithi county) Kenya respectively, as described below; and for this reason they were selected for this agroecology assessment.

Busia county is in the Western part of the country where agriculture is the main economic activity of the region. The land holdings range from 0.4 ha for small-scale farmers to 6 ha for large-scale farming, 84 percent of the crop output is for subsistence use (USAID, 2014). Approximately, 36 percent of the total arable land in the area is under maize, whereas sorghum, cassava, cash crops occupy 10 percent, 14 percent and 10 percent respectively. The observed climate extremities include increased frequency of drought occurrence from ten years to every two-three years adversely affecting productivity which is mainly rain-fed. Agricultural productivity is further affected by declining soil fertility (MoALF, 2016).

In Busia county, the SINGI CBO is recognized as one of the institutions promoting bio-diversification through the growth of African leafy vegetables (ALV) to enhance sustainability and the reclamation of once diminishing nutritious genetic resources. Aside from promoting diversification, SINGI also equips farmers with knowledge on (i) integrated management of soil fertility and pest through the production of own compost and intercropping; and (ii) input substitution using manure, crop residues, compost and biopesticides. Farmers with acidic soils are encouraged to use manure and wood ash to increase the availability of nutrients to the crops. Other practices taught include water and soil conservation techniques (raised beds, semi-circular bunds/*mandalas* and keyhole gardens). The transfer of technology is through farmer-to-farmer training and demonstration farms set up by farmer groups in different locations within the county. SINGI was established in 2005 and has grown to a membership of over 50 groups with an average of 20 farmers per group.

Tharaka-Nithi and Meru county are located in the Eastern part of Kenya where agriculture is the main economic activity. The projected changes in climate include an increase in moderate temperatures which may lead to future moisture stress (MoALF, 2017). The main cultivated crops include green grams, millet, sorghum, cowpeas, pigeon peas, maize and beans (Recha *et al.*, 2017).

In Eastern Kenya, the ICE promotes agro-ecological farming practices such as the use of indigenous crop varieties, agroforestry, organic farming and livelihood diversification among smallholder farmers. ICE has successfully conducted training programmes geared towards food sovereignty, that led to several impacts, including: (i) the revived use of twelve varieties of indigenous seeds; (ii) erection of effective cereal storage structures for over 100 households; (iii) equipping 470 households with water harvesting and storage tanks; and (iv) the adoption of agroecological practices such as agro-forestry, terracing, water and soil conservation techniques by at least 800 farmers.

The reduction of industrial input usage can be regarded as level one agroecology, while the substitution of conventional practices with agroecological practices can be regarded as level two agroecology (Gliessman, 2016; Mier *et al.*, 2018). Based on the training and eventual adoption of the practices, farmers were trained on (to varying degrees), farmer affiliation with SINGI and ICE for more than five years was considered to be in "agroecological transition" or "agroecological".

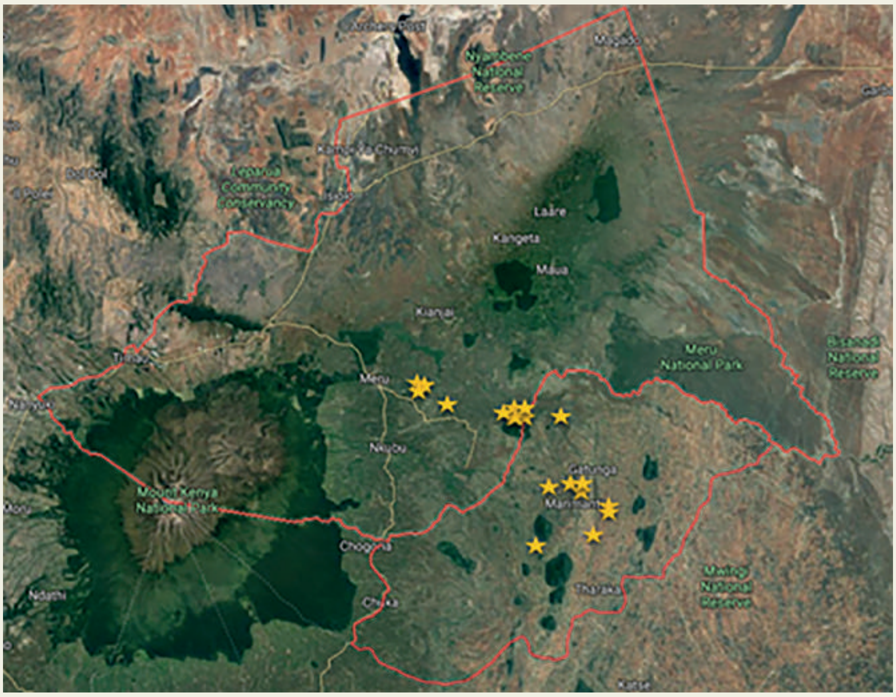
Sampling Design

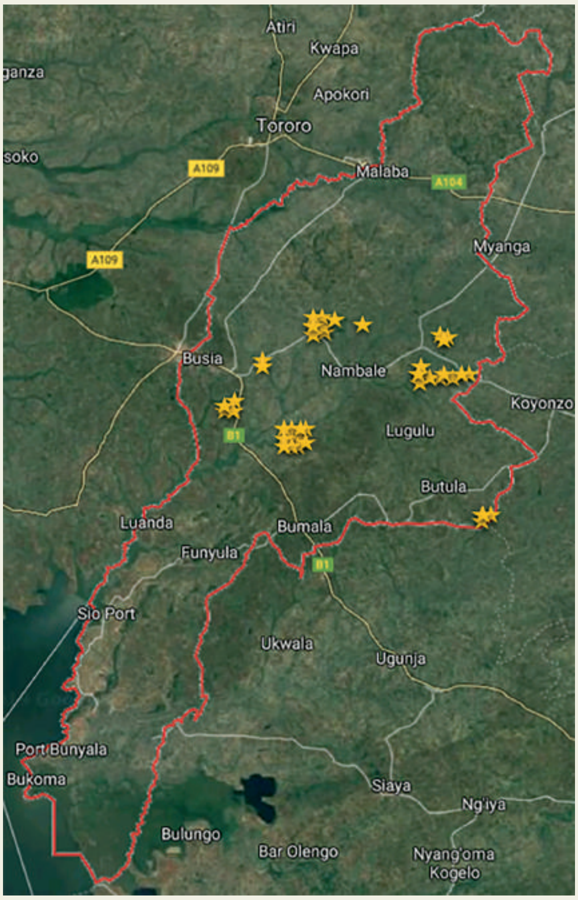
The sampling approach was based on spatial distribution and randomized sampling of farmers. The spatial sampling focused on 88 farmers from four agroecological zones (AEZs), spanning in three county regions in Kenya namely Busia, Meru and Tharaka-Nithi. The distribution across county regions was to enable maximum heterogeneity of the sample in terms of gender, age and wealth. Farmers sampled were further categorized as agroecological (n=44) and non-agroecological (n=44) (**Table 4**).

The agroecological farmers (n=23) from AEZ LM1 and LM2 were randomly selected from SINGI'S membership list, while the rest of agroecological farmers (n=21) located in AEZ LM5 and IL 5 were randomly selected from a membership list of farmer groups affiliated with ICE (**Table 4**).

FIGURE 17.

MAPS OF THE THREE KENYAN COUNTIES (MERU, THARAKA-NITHI AND BUSIA (SECOND PICTURE) AND THE SAMPLING SITES





For comparison purposes, non-agroecological farmers (n=44) were randomly selected from the same regions (Busia, Meru and Tharaka-Nithi) to closely match the agroecological/climatic conditions, livelihood strategies and landholding patterns of the agroecological producers. Key trained personnel (extension officers) from SINGI and ICE identified a list of non-agroecological farmers within their areas of operation who were later picked randomly for participation in the survey.

The data collection process through the survey was conducted beginning of July, which is typically the end of the wet season or harvesting for the cropping season. Based on the Kenya Meteorological Department review of the long rain season of 2019 (March-April-May), the seasonal rainfall was characterized by late-onset and poor (below average) temporal and spatial distribution (KMD, 2019).

TABLE 4.

NUMBERS OF FARMERS SAMPLED FROM FOUR AGROECOLOGICAL ZONES IN KENYA

ZONE	CHARACTERISTICS OF ZONES		NUMBERS OF FARMERS IN EACH ZONE	
	Altitude (m)	Min. annual rainfall (mm)	Agroecological farmers	Non-agroecological farmers
LM1	1200 -1440	1800-2000	23	23
LM2	1200-1350	1550-1800		
LM5	<900-1800	500-900	21	21
IL 5	<900m	500-900		
Total			44	44

Characteristics of the AEZs: Western Kenya, AEZ LM1 – Lower Midland Sugarcane Zone (sub-counties sampled Nambale, Matayos and Butula); AEZ LM2 – Marginal Sugarcane Zone (sub-counties sampled Teso North), the main staple crop grown in the sampled sub-counties is maize. Eastern Kenya, AEZ LM5 – Lower Midland Livestock – Millet Zone (sub-counties sampled Tharaka-Nithi); AEZ IL 5 – Inner Lowland Livestock – Millet Zone (sub-county sampled – Imenti North) (Jaetzold et al.*, 2011).*

Specificities for the Kenyan Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists (SHARP) survey

- The survey was administered via a SAMSUNG Tablet Galaxy Tab A.
- Four enumerators with minimum a BSc degree received training on SHARP Tool from 17 to 20 of June 2019 and conducted the survey between 1 and 14 of July under the supervision of a research consultant.

Overall Findings of the Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists (SHARP) resilience assessment

There was no statistically relevant difference between the three counties in regard to their performance in SHARP even though they were located in different AEZs. Due to the homogeneity of the results, the differences in SHARP performance were analysed wholly as either agroecological or non-agroecological systems without regard for the AEZs.

A statistical analysis **indicated a significant difference ($p<0.001$) between the average mean overall SHARP scores for the agroecological and control group farmers. The agroecological farmer mean score was 5.2 percent higher than the non-agroecological farmer** (Table 5).

The resilience scores of both the agroecological (59.9 percent) and non-agroecological farmers (54.7 percent) characterise the systems as mid-level climate resilience which implies that the farmers have certain abilities and knowledge to withstand unexpected shocks and climate variability. However, there is still a need to further strengthen their capacity to adapt to climate change (Hernandez-Lagana, Nakwang and Muhamad, 2018).

For the **agroecosystem resilience indicators, significant statistical differences were observed for 7 of the 13 agroecosystem indicators whereby the scores for the agroecological farmers were higher than for the non-agroecological farmers ($p<0.05$)** (Figure 18).

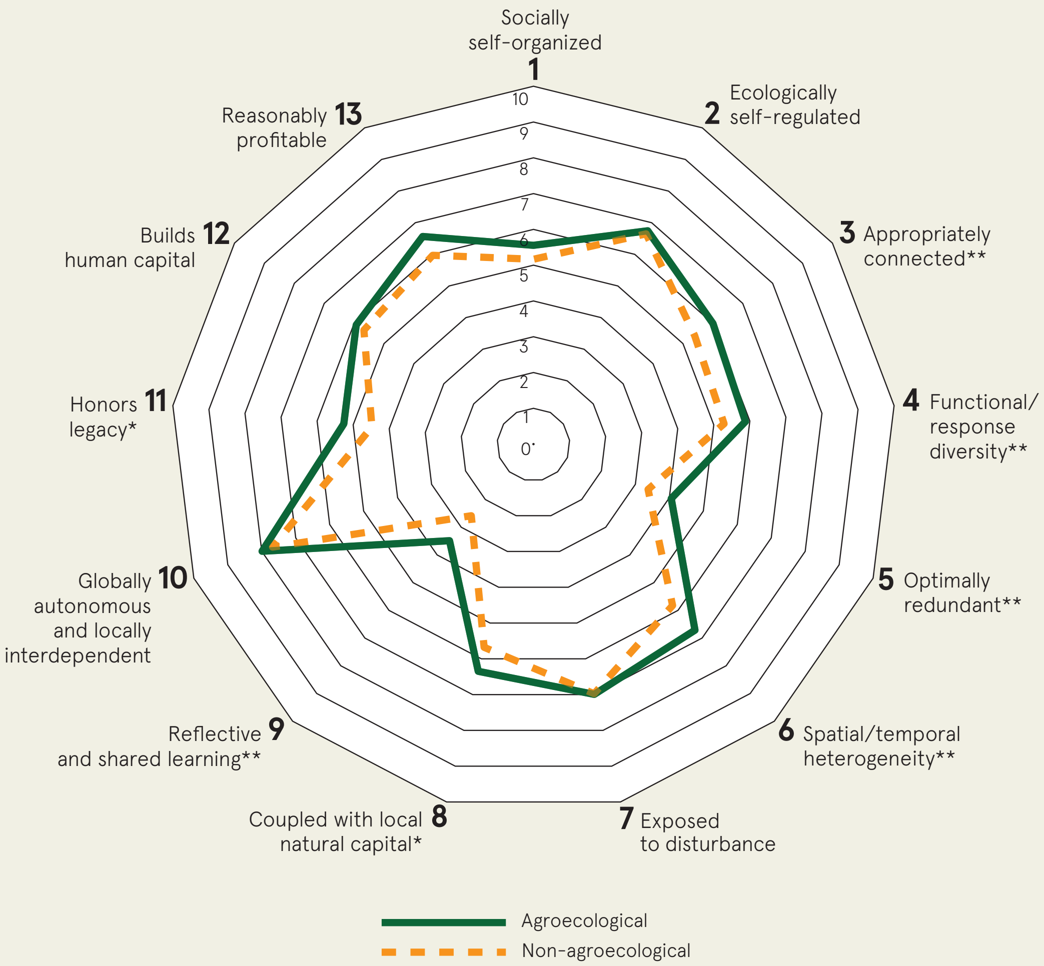
TABLE 5.

SUMMARY OF SHARP DATASET SCORES FOR SAMPLED FARMERS

VARIABLE	TYPE OF FARMER	SAMPLE No.	MEAN (%)	MIN (%)	MAX (%)	STANDARD DEVIATION	COEFFICIENT OF VARIATION (%)
SHARP scores	Agroecological	44	59.9	43.8	75.9	±7.1	10.7
	Non-agroecological	44	54.7	40.2	67.7	±6.6	10.3

FIGURE 18.

AGROECOLOGICAL AND NON-AGROECOLOGICAL MEAN SCORES FOR 13 AGROECOSYSTEM INDICATORS FOR CLIMATE RESILIENCE



*Significant differences were observed in 7 of 13 resilience indicators determined by t-test and indicated as * p<0.05, ** p<0.01 *** p>0.001. Agroecological mean scores were higher compared to the non-agroecological farm system for all the resilience indicators that are statistically different.*

At the sub-indicator level, significant differences in mean scores were observed in 12 of 92 sub-indicators (p<0.05). Agroecological farmers had higher mean scores in 11 of these 12 sub-indicators. At the module level, mean scores for 6 of 36 modules were significantly higher for the agroecological farmers than the non-agroecological farmers.

Priority ranking

Based on the priority ranking assessment (SHARP's self-assessed importance from the technical, adequacy and importance scores of each module as generated by SHARP tool) as shown in **Table 6**, both the agroecological and non-agroecological farmers identified similar modules as priorities, sharing 15 of the top 20 modules for intervention.

TABLE 6.

PRIORITY RANKING ASSESSMENT (GREATEST PRIORITIES ON TOP AND LEAST PRIORITIES AT THE END OF THE TABLE) FOR AGROECOLOGICAL AND NON-AGROECOLOGICAL FARM SYSTEMS BASED ON TECHNICAL, ADEQUACY AND IMPORTANCE SCORES OF EACH SHARP MODULE. THE LOWEST SCORING MODULES ARE CONSIDERED OF THE HIGHEST PRIORITY AND REQUIRING INTERVENTION

SHARP FARM SYSTEM MODULE	AGROECOLOGICAL FARM SYSTEM	NON-AGROECOLOGICAL FARM SYSTEM
Insurance	1	1[a]
Animal Breeding Practices	2	2[a]
Non-Farm Income Generating Activities	3	7[a]
Water Access	4	4[a]
Land Access	5	8[a]
Leguminous Plants and Trees	30	32
Animal Nutrition and Health	31	30
Decision Making (Household Level)	32	33
Access to financial Services	33	36
Major Productive Assets	34	31
Information and Communication Technologies (ICTs)	35	34
Decision Making (Farm Management)	36	35

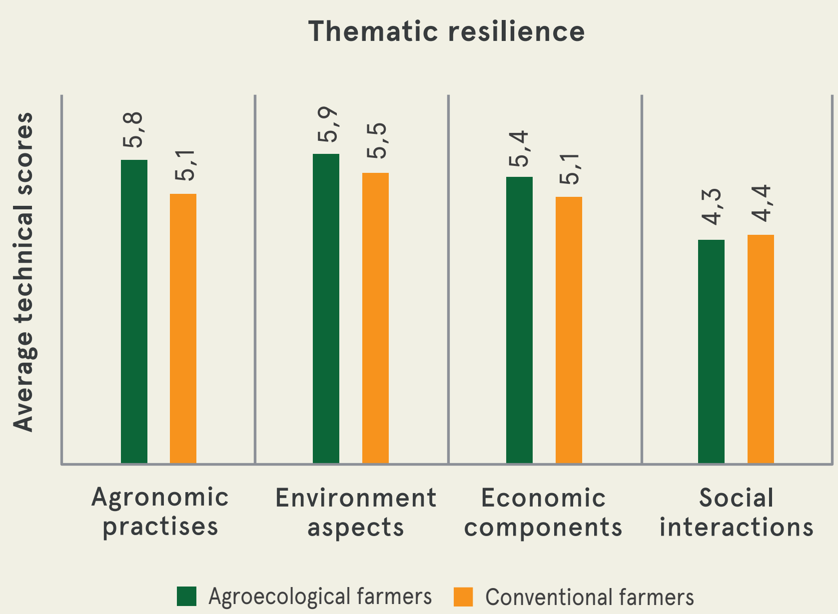
Domain results

SHARP results were also assessed based on the four domain levels: agronomic practises, environmental aspects, social interactions and economic components as shown in **Figure 19**. Based on the technical scores (4.3-5.9), the farmers indicate a mid-level resilience.

A significant difference was observed in the agronomic practises domain (p<0.001) which covered modules on agricultural production, crop production, intercropping, pest management, animal production, animal health and nutrition, new varieties and breeds, trees and information access.

FIGURE 19.

AVERAGE TECHNICAL SCORES FOR THE FOUR DOMAINS



Detailed results: agroecosystem resilience indicators

This chapter provides a detailed analysis of the agroecosystem resilience indicators' results.

Socially self-organized indicator

The *socially self-organized* indicator assesses the farmers' ability to organize into grassroots networks and institutions such as co-ops, farmer's markets and community sustainability associations. There were no significant differences between the two farm systems. Agroecological and non-agroecological farmers showed similar access patterns to communal land resource and financial support.

To assess this organization regarding access to local farm markets the two measurable variables considered for this indicator were (i) household to market distance and (ii) access to market price information; however, it is important to highlight that a multiplicity of indicators can be used (Chamberlin and Jayne, 2013) to proxy this.

Most farmers indicated having access to a local market within a 10 km radius. The findings are consistent with a study by Chamberlin and Jayne (2013), indicating household to market distances of roughly 0.85 km which implied that even remote villages that lacked physical access to infrastructures such as all-weather roads and electricity, still had (i) a large number of small traders competing for local purchases and (ii) the ability to choose to sell their grain surpluses at the farm gate. The proximity to markets signifies a local food movement which is smaller and easily adaptable to changing conditions of the local groups when compared to larger groups at a regional or national level, hence more resilient (Cabell and Oelofse, 2012).

A slight difference was observed with market pricing decisions as 48 percent% of agroecological farmers compared to 58 percent% of non-agroecological farmers set product prices based on market prices. According to Alene *et al.* (2008), price information in Kenya is mostly published in newspapers and only for the major markets which are not accessible to the majority of the farmers. This results in the farmers relying on physically gathering information from local assembly markets or by letting main dealers/buyers to set the price. The farmers reported that market prices tend to be volatile yielding lower returns during surplus harvest seasons, which has a direct impact on their income and indirect impact on the resilience of the farmer.

Cooperatives have the benefit of organizing farmers into strong producer and marketing associations; however, only 3 of the 88 farmers sampled (all agroecological farmers), declared to have relied on cooperative organizations to set the market prices for their agricultural produce.

The priority ranking assessment indicates that both farmer groups deemed group membership as a priority of near-equal importance, priority No. 21 and No. 17 respectively for the agroecological and non-agroecological farm systems.

Ecologically self-regulated indicator

There were no significant differences observed for the agroecological and non-agroecological farming systems for the *ecologically self-regulated* indicator. According to Cabell and Oelofse (2012), a self-regulating agroecosystem is governed by the feedback mechanisms created through ecosystem services such as the hydrological cycle, biodiversity and soil resources.

Self-regulation was assessed using sub-indicators such as soil health, environmental-friendly energy sources, presence of ecosystem engineers (buffer zones), biodiversity (perennials and trees), utilization of local animal breeds and crop varieties, fertilizer practices and leguminous plants. There were no significant differences between the farming systems at the sub-indicator level, as the majority of the agroecological (90 percent) and non-agroecological farmers (88 percent) were observed to utilize local animal breeds and local crop varieties. Likewise, 100 percent and 95 percent of the agroecological and non-agroecological farmers (respectively) grew perennial crops while both farming systems appeared to incorporate agroforestry based on the presence of trees on their farms. Traditional varieties offer great defences/buffer capacity against vulnerability and enhance harvest security in the midst of diseases, pests, drought and other stresses (Altieri, 2009).

Due to a lack of waste management services in the areas sampled, farmers utilizing synthetic pesticides were noted to dispose of their containers through burning, burying in soil or throwing in pit latrines. Poor disposal methods for pesticide waste may result in biodiversity loss, soil pollution and health risks.

Based on the priority ranking assessment both farm systems indicated high importance (ranked as priority 11) for farm inputs.

Appropriately connected indicator

Significant statistical differences ($p<0.01$) were evident between the agroecological and non-agroecological systems with a higher mean score (6.1 percent) for agroecological farmers (**Figure 18** and **Table 5**). As one of the resilience indicators for agroecosystems, *appropriately connected* is a measure of the dynamic relationships and collaborations within the agrosystem over a spatial and temporal scale (Cabell and Oelofse, 2012).

The relationships at the farm/field level cover aspects of biological interactions, for example vegetation growth through nutrient cycling, predator/prey interactions, competition, commensalism and successional changes (Altieri, 2002). Connectedness outside the farm level reviewed existing networks between the farmers, suppliers, fellow farmers and consumers. Ties with multiple suppliers, outlets and fellow farmers ensure non-essentiality and continued functionality within an agrosystem in case one of the ties is cut off (Cabell and Oelofse, 2012). The sub-indicators reviewed to verify these collaborations included access to information (market prices, weather forecast and climate adaptation practices), the existence of multiple suppliers for farm inputs, access to markets and veterinary services and the level of trust among community members.

One of the farm-level relationships were assessed through the sub-indicator of "intercropping", where there were no significant differences between the farm systems. This may imply that non-agroecological farming for smallholder farmers in Kenya is not strictly a monoculture. According to Adamtey *et al.* (2016), non-agroecological farming for smallholder farmers in sub-Saharan Africa consists of maize-mixed farming where farmers grow more than one crop species for subsistent and commercial purposes. The agroecological farmers were observed to incorporate intercropping practices as a means of crop diversification.

For the exogenous relationships (ties outside the farm level), significant differences were observed between the two farm systems through the sub-indicators "access to information" and "access to market". The agroecological farmers indicated higher access to information to climate adaptation practices and weather patterns.

The information pathways for climate change adaptation and weather patterns are most likely due to extension services provided through NGOs such as ICE/SINGI. According to past research on sources of agricultural information in Kenya (Goldberger, 2008), NGOs are the most important source of agricultural information for sustainable methods such as agroecology and organic farming. The information is disseminated through formal workshops, exposure visits, demonstration farms and conversations with NGO staff. Some of the organic techniques taught and practised by the agroecological farmers included *mazimbuko* trenches, *mandala*, raised beds and keyhole kitchens which are paramount for water conservation and consequently, climate adaptation. Access to these extension services increases the probability of adopting different climate-smart/adaptation practices which would hedge the farmer against climate change (Belay *et al.*, 2017).

Access to markets for the *appropriately connected* indicator was assessed through the ability of the farmers to sell their produce when desired and the use of certification schemes to increase product value. Based on the mean scores, the agroecological farmers had higher chances of selling their produce when desired compared to non-agroecological farmers. However, only seven percent of all farmers were observed to participate in certification schemes. The farmers cited various reasons for the lack of participation in the schemes, the main one being non-existence of these within their reach.

Based on the priority scores, agroecological farmers indicated community cooperation as of greater priority (ranked 16) compared to non-agroecological farm systems (ranked 28). This is in line with the agroecology principles in which the links to the members of the community for knowledge sharing and problem solving are key to strengthen sustainability and resilience.

Functional and response diversity indicator

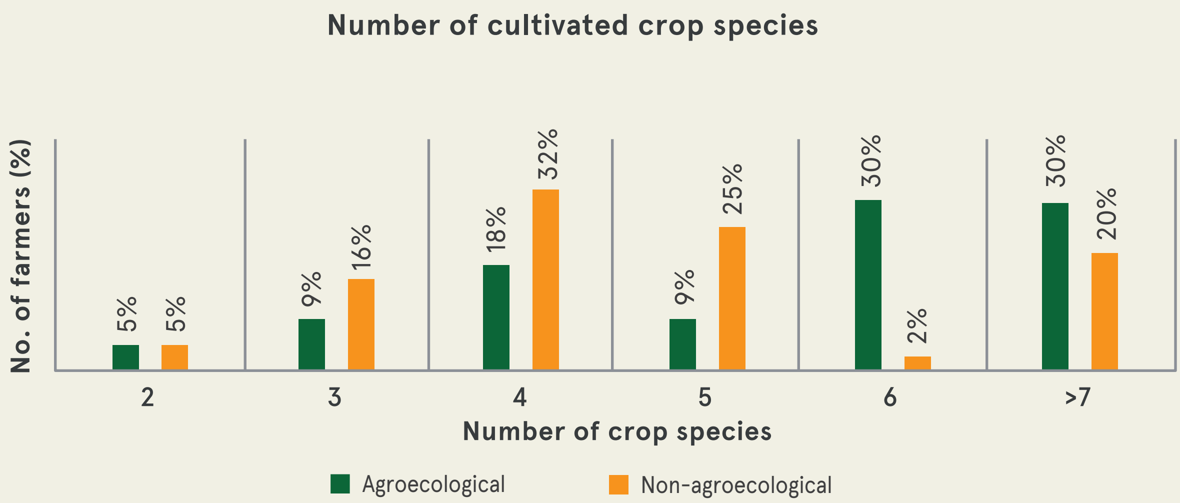
Significant differences were observed between the mean scores of the agroecological and non-agroecological systems ($p<0.01$) for this indicator. *Functional and response diversity* was assessed using sub-indicators such as diversity in crop species, tree species, animal species, agricultural production activities, food, landscape and fertilizer inputs; assets owned; non-farm income-generating activities; membership in groups; pest and disease management practices. Significant differences were observed in species diversity ($p<0.001$) and group membership ($p<0.01$).

Higher diversity in crop production was evident with 69 percent of agroecological farmers, as they tend to mix both seasonal and perennial crops in the same system (usually more than five seasonal and perennial species), compared to only 48 percent of non-agroecological farmers (**Figure 20**). According to Folke (2006), biological diversity is essential to a system's ability to attain resilience as it improves the capacity for a system to self-organize both in absorbing disturbance, regenerating and re-organizing. As biological diversity, economic and social diversity are important for climate resilience as they serve as a buffer when certain aspects of the farm system are jeopardised.

The practice of crop diversification among agroecological farmers was likely to be supported by capacitating NGOs and CBO groups, as well as the spreading of awareness related to climate risks. Indeed, agroecological farmers appear to have higher adaptive capacity than non-agroecological farmers.

FIGURE 20.

NUMBER OF CROP SPECIES GROWN



Agroecological farmers were also noted to have active membership in multiple groups compared to non-agroecological farmers. Both farmer groups regarded additional and diversified income from non-farm activities as one of the top ten priorities to enable household food security and enhanced resilience (there was also no statistical difference for this sub-indicator).

Optimally redundant indicator

Optimal redundancy serves to ensure that elements perform multiple functions as multiple elements could perform a single function in an agroecosystem (Cabell and Oelofse, 2012). In essence, an ecosystem's redundancy serves as the backup and ensures functioning should any element fail in case of shock. There were significant differences between the agroecological farmers and non-agroecological farmers ($p<0.01$) (**Figure 18**). Redundancy was marked by the access to multiple sources of water, energy, nutrients, seeds, financial sources; access to land; multiple varieties of crops and animal breeds; animal nutrition; food stocks and presence of cereal banks (see **Box 1** below on that particular aspect). Of particular importance on these sub-indicators was the varietal diversity, which captured the number of breeds owned and the number of varieties cultivated ($p<0.01$). Similar to crop diversification, agroecological farmers had a higher reliance on multiple traditional crops and animal varieties.

The average private land area owned for the sampled farmers was 1.47 ha. Access to communal land resources for pasture and other agricultural activities was low, as only 17 percent of all farmers had access to communal agricultural land and 23 percent had access to pasture land. Increased farm size has a positive influence on adaptation strategies as it increases the probability of planting numerous fodder trees and integrating crop with livestock production, therefore allowing ecological redundancy which contributes to resilience-building of agroecosystems. It also provides an opportunity for crop diversification, thereby distributing risks associated with climate variability. This corroborates Alene *et al.* (2008) who hypothesised that a minor increase in access to land per capita (one percent) would boost market participation of farmers by 11 percent. Improved market participation will strengthen the multiple networks of the local food movement as well as increased income for the individual farmer positively contributing to their resilience levels.

BOX 3: CEREAL BANK

Seed granary for the agroecological farmers group in AEZ IL 5. a) The equipment was provided by Biovision Foundation and ICE NGO. A farmer's testimonial stated that: the equipment allows the farmers to store their seeds to up to a period of three years, which is more effective than storing seeds in the (b) gunny bags. The seed granary is also useful to farmers not only to store seeds for the next cropping season, but also for food in emergencies during the failed long rains. The farmers were not actively involved in cereal banks, however they pointed out the potential of cereal banks to stabilize prices/as a source of credit. If cereal banks were set-up as feature within their farmer's group, during periods of urgent need, one could have an option of borrowing money from the farmer groups against his/her seeds instead of selling them at extremely low prices due to urgent and unexpected needs.

Based on the priority ranking assessment, both farmer groups indicated access to land as a major priority (ranked 5 and 8 for agroecological and non-agroecological farmers respectively).

Spatial and temporal heterogeneity indicator

This indicator looks into the patchiness of the farm system and across the landscape. As such, it comprises aspects related to the diversity of across and within agricultural activities, practices used for resources management and landscape diversification.

Agroecological farmers were observed to have a significantly higher degree of spatial and temporal heterogeneity ($p<0.01$). At the sub-indicator level, these differences were evident in temporal heterogeneity ($p<0.01$) as intercropping, and a mix of crop cultivation ($p<0.01$).

Agroecological farmers more commonly used land management practices such as agroforestry, crop rotation and manure/composting to increase the temporal and spatial heterogeneity when compared to their non-agroecological counterparts.

This can be attributed to the higher access of agroecological farmers to technological know-how through farmer to farmer training that allowed the diffusion and adoption of such techniques. The adoption of the techniques increases the adaptive management within the agroecological systems when compared to the non-agroecological systems. Based on the priority ranking assessment, non-agroecological farm systems had a higher priority to learn land management practices (ranked 12) compared to agroecological farm systems (ranked 28) (**Annex 7.5**). The agroecological farmers' group also indicated a higher mix of crops through planting more perennial and seasonal crop species.

Exposed to disturbance indicator

There were no significant differences between agroecological and non-agroecological farmers with regard to this indicator, implying a similar level of exposure to disturbances. At the sub-indicator level, exposure to disturbance was denoted by the presence and management of weeds; climate-related relate shocks experienced; the presence of buffer zones; use of pest management practices; the presence of animal diseases; water and soil quality and external financial support received. Due to the similar geographic setting, the farmers reported experiencing comparable disturbances in climate-related events such as rainfall variability and other shocks hence the lack of differences for this resilience indicator. These findings were similar to a study by Heckelman *et al.* (2018) who found no significant differences between organic and non-agroecological rice systems due to both systems experiencing comparable levels of multiple small-scale disturbances.

Coupled with local and natural capital indicator

The *coupled with local and natural capital* indicator is an assessment of the system's ability to recycle and reuse waste and encourage the system to live within its own means (Heckelman, Smukler and Wittman, 2018).

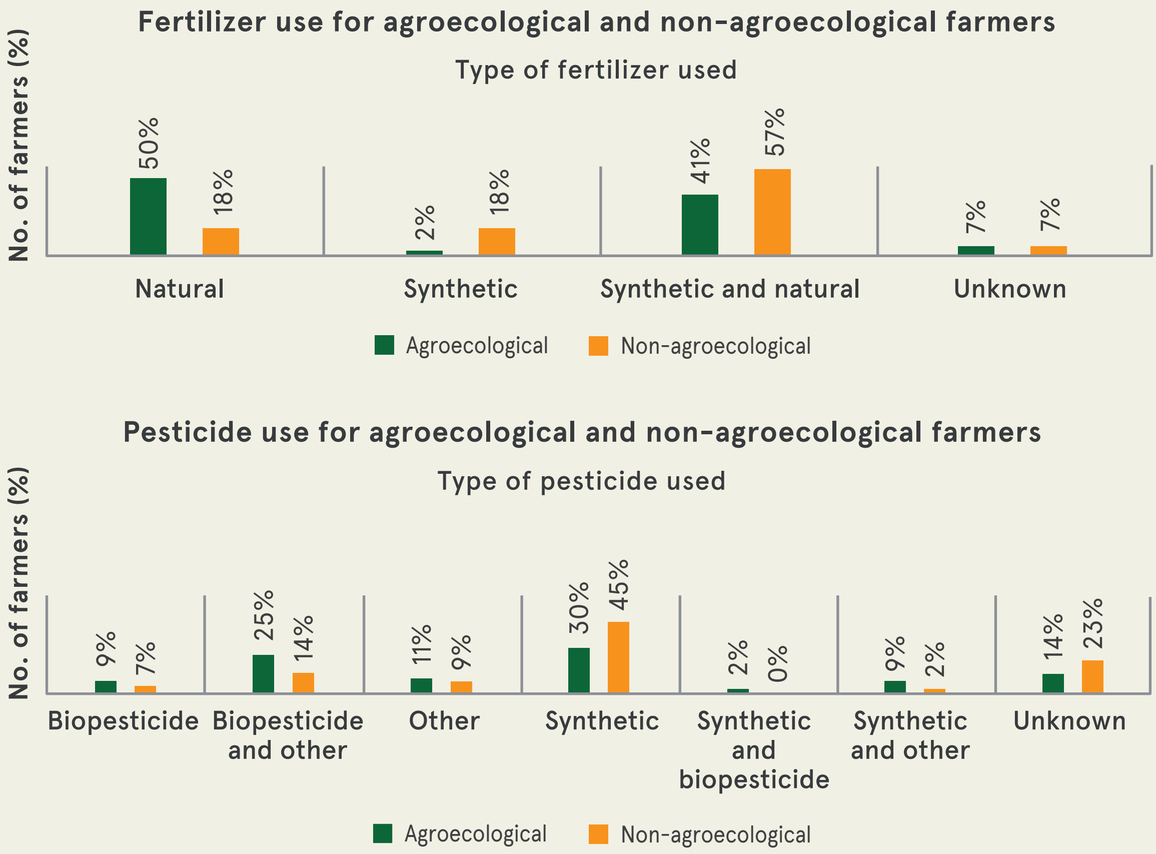
It was measured in terms of land improving practices (use of techniques improving the spatial and temporal heterogeneity, presence of leguminous plants and trees, use of natural fertilizers), energy and water conservation practices, water quality, pest management practices, the presence and increase/decrease trend of trees within the farm. Although there were significant differences reported for the use of land improving management practices, there were no statistical differences observed in the fertilization practices, growth of leguminous trees and pest management practices. Ultimately, due to the differences in land management, significant differences were observed ($p<0.05$) in the coupled with local and natural capital indicator.

Further assessment of the types of inputs used in the farm systems revealed that approximately 50 percent of the agroecological farmers relied on natural fertilizers compared to 18 percent of non-agroecological farmers. Non-agroecological farmers mostly applied a mix of natural and synthetic fertilizers (57 percent) compared to agroecological farmers (41 percent) (**Figure 21**). Overall, more agroecological farmers relied on crop and farm residues, compost and manure for fertilization developing a higher adaptive capacity of converting waste to a resource which contributes to the preservation of the natural resource base, increasing climate resilience and sustainability of the farm systems.

For the agroecological farmers, 30 percent applied synthetic pesticides when compared to 45 percent of the non-agroecological farmers. The use of biopesticides was comparable between the two farm systems (nine percent and seven percent respectively for agroecological and non-agroecological). The lower use of synthetic pesticides and higher use of biopesticide and other methods for pest control among agroecological farmers is reflective of the level of awareness of environmental quality and soil health effects. External input substitution is not only a maker of agroecological transition (Gliessman, 2016) but it also denotes the reliance of natural systems to self-regulate making it more resilient (Cabell and Oelofse, 2012). Based on the ranking assessment, pest management practices emerged as one of the top priorities of near-equal importance for both agroecological (No. 12) and non-agroecological (No. 13) farmers.

FIGURE 21.

A COMPARISON OF THE SYNTHETIC AND NATURAL INPUT USE BETWEEN AGROECOLOGICAL AND NON-AGROECOLOGICAL FARMERS. APPROXIMATELY, 55 PERCENT OF THE AGROECOLOGICAL FARMERS RELIED ON NATURAL FERTILIZERS COMPARED TO 18 PERCENT OF THE NON-AGROECOLOGICAL FARMERS



Reflective and shared learning indicator

Active membership in agricultural groups provides a platform for reflection and shared learning leading to an increase in the adaptive capacity of the actors in the agro system. The actors (farmers) are able to anticipate the future based on experiences rather than the present conditions. The adaptive capacity will, therefore, trickle down to the system (farm) itself (Cabell and Oelofse, 2012). The SHARP methodology attempts to capture this through the inclusion of questions related to group membership, access to information and changed behaviour after expected and unexpected shocks are experienced.

Significant differences were observed between the two farm systems for the reflective and shared learning indicator ($p<0.01$). At the sub-indicator level, agroecological farmers showed significantly higher participation ($p<0.001$) in agri-related groups compared to non-agroecological farmers.

Agroecological farmers also indicated better access to information on the weather forecast ($p<0.05$). The access to weather information by agroecological farmers means they are better able to plan their agricultural activities which leads to informed adaptation planning and higher resilience level.

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Globally autonomous and locally interdependent indicator

No significant differences were observed between the two farm systems for the *globally autonomous and locally interdependent* indicator. Reliance on exogenous controls such as global markets, regulations and subsidies on agricultural production tends to reduce resilience and adaptive capacity of the agro system (Cabell and Oelofse, 2012; Milestad *et al.*, 2010). Therefore, resilient systems are globally autonomous however, they also establish effective collaborations and interlinkages at a local level.

At the sub-indicator level, there were no significant differences. Global autonomy was assessed using the ability of farmers to breed at the local level, reliance on local species, access to local markets, reliance on local energy sources, locally sourced food, purpose of production (for selling/on-farm production).

Honour's legacy indicator

Honour's legacy is a measure of the preservation and use of traditional and indigenous knowledge in the management of the farm. Assessment of the indicator was based on sub-indicators such as the engagement of elders in the community, preservation of traditional knowledge, customary mechanisms, tree products, disease management and use of new varieties.

Agroecological farmers scored significantly higher in the *honour's legacy* indicator ($p<0.1$). At the sub-indicator level, agroecological farmers were observed to have a higher integration of tree products for agricultural production as well as anthropogenic use. Due to the transfer of traditional knowledge through their associative groups, the farmers were more likely to use trees for natural remedies, pesticide and soil fertilizer.

Builds human capital indicator

With regard to this indicator, "a system that builds human capital mobilizes social relationships and resources that improve household well-being, economic activity; technology, infrastructure, individual skills and abilities and facilitates social organization and norms, as well as formal and informal networks" (Cabell and Oelofse, 2012; Heckelman *et al.*, 2018).

There were no significant differences between the agroecological and non-agroecological farmers. At the sub-indicator level, human capital was assessed through social capital, animal care, education, household equality, ownership of ICT devices and household health. The non-agroecological farm system had significantly higher scores than the agroecological farmers for social capital which was evident for the farmers in AEZ LM 2 ($p<0.05$). Social capital was assessed through community organization of festivals linked to key moments of their season (e.g. coinciding with harvest, planting, flowering). Non-agroecological farmers in AEZ LM 2 reported festival celebrations during harvest season, closely linked to religious festivities in the area.

*Reasonably profitable i*ndicator

This indicator aims to assess the extent to which farmers and farm workers can earn a liveable wage through agriculture and other non-farm activities, and capture whether the agriculture sector is not relying on distortionary subsidies to be profitable. Profitability was assessed through financial support, income sources, access to markets, assets owned, insurance, savings and post-harvest handling.

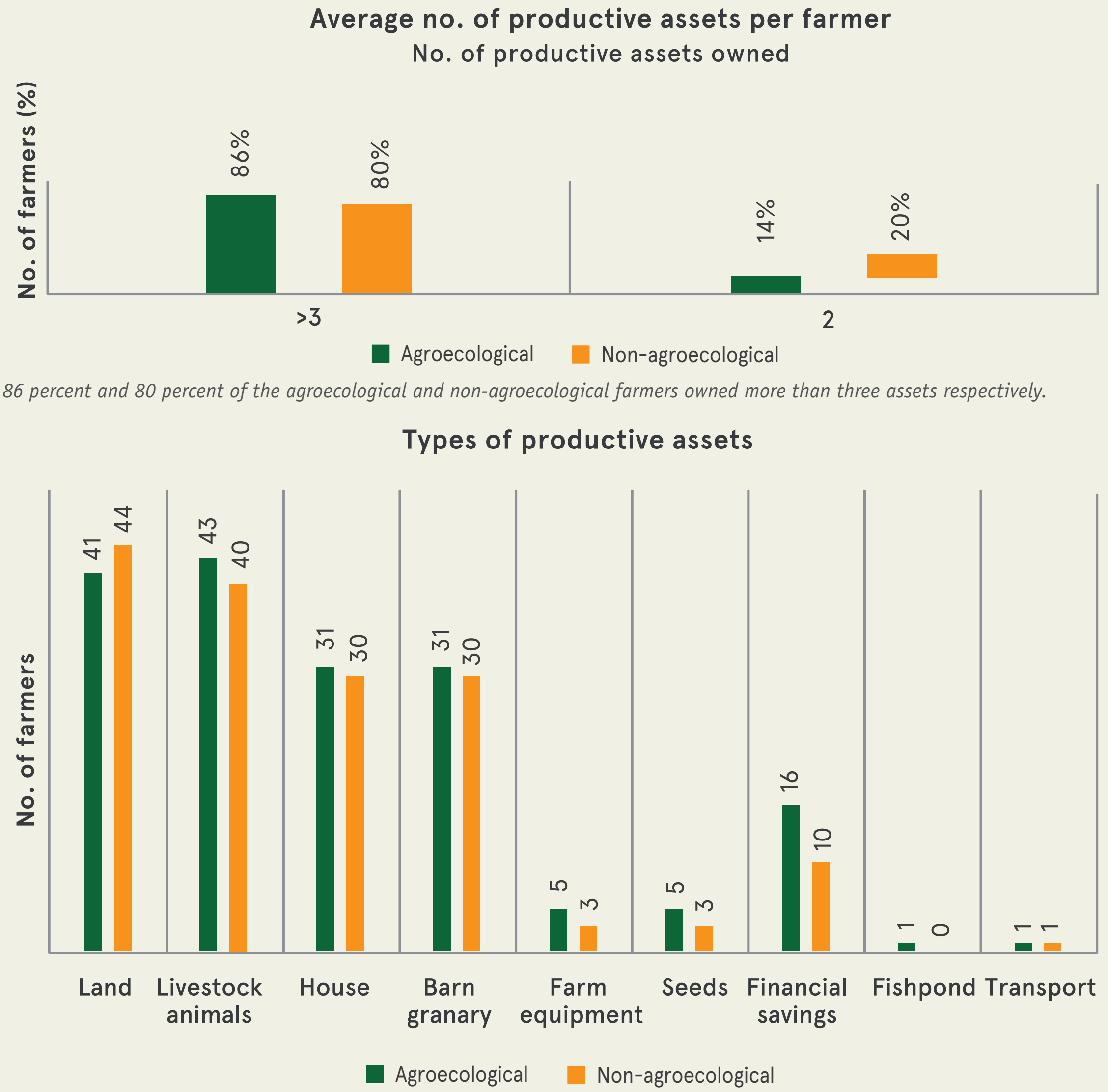
Through the analysis, it was found that there were no significant differences between agroecological and non-agroecological farmers for the "reasonably profitable" indicator.

At the module level and sub-indicator level, insurance had the lowest average scores for both farm systems (**Annex 4**) and ranking as the highest priority for farmers (**Table 6**). The farmers expressed having no access to insurance.

An assessment of the productive assets owned indicated no significant differences for the number of assets owned per farmer (**Figure 22A**) as well as the type of assets owned (**Figure 22** b) between the agroecological and non-agroecological farmers. The most commonly owned assets in both farm systems were land and livestock animals.

FIGURE 22.

A) NUMBER OF PRODUCTIVE ASSETS OWNED BY AGROECOLOGICAL AND NON-AGROECOLOGICAL FARMERS
B) TYPES OF PRODUCTIVE ASSETS OWNED BY THE FARMERS



a) 86 percent and 80 percent of the agroecological and non-agroecological farmers owned more than three assets respectively.

b) The most common assets owned by both agroecological and non-agroecological farmers included: land, livestock animals, infrastructure (house and barn granary).

Higher income per hectare has been observed in different markets, for instance in the United States, 2 ha farms exhibit higher yields and income than non-agroecological large-scale farms. Polycultures exhibit higher productivity in the form of harvestable products per unit area which results in yield advantages ranging from 20 percent to 60 percent, compared to monocultures, due to reduced losses by weeds, insects and diseases (because of the presence of multiple species) and more efficient utilization of available resources of water, light and nutrients. However, higher profitability arises from farmer-to-consumer solidarity (direct linkages between farmer and markets) as well as payment of premium prices for their local and organic products (Altieri, 2009).

Despite higher harvestable products, agroecological farmers were observed to attain similar profitability/income levels with non-agroecological farmers. Hindrances to higher income per hectare arise could be arising from the lack of farmer to market solidarity and the reliance on volatile market prices. Policies supporting farmer to farmer networks which would set/stabilize product prices will result in fair trade and higher incomes for the farmers which will hedge in resilience. This also shows that there is a need to promote circular and short circuit markets that brings consumers closer to farmers. Different NGOs working with agroecological farmers will need also to sensitize consumers on the importance of agroecological produced products.

Farmers also expressed the need for value addition in order to fetch higher prices for their products. Simple infrastructure, such as posho mills within the communities, would allow a farmer to grind their products fetching higher prices in the market.

Conclusions

This comparative assessment between agroecological and non-agroecological farm systems using FAO's SHARP methodology indicated a difference in climate resilience. In general, the agroecological farmers were more resilient with 5.2% higher mean score. The assessment was based on 13 agroecosystem resilience indicators for socio-ecological systems (Cabell and Oelofse, 2012). Out of these 13 indicators, 7 indicators scored significantly higher in agroecological systems than in the non-agroecological farm systems.

Agroecological farmers indicated a higher significant statistical difference for *the appropriately connected* indicator. The farmers had better access to information on climate adaptation practises and weather forecast and better access to markets which was indicated by the agroecological farmers' ability to sell the produce when desired as well as higher participation in certification schemes relative to their non-agroecological counterparts. Access of information was mostly from NGOs.

Significant differences were observed between the mean scores of the agroecological and non-agroecological systems for the *function and diversity redundancy* indicator. Agroecological performed better in this indicator in particular due to higher species diversity with at least 69 percent of the agroecological farmers growing more than five crop species compared to only 47 percent of the non-agroecological farmers. The agroecological farmers also had higher participation in agriculture-focused groups.

There were significant differences ($p<0.01$) for the *optimally redundant* indicator. Optimal redundancy was marked by multiple varieties of crop and animal breeds. Agroecological farmers had a higher reliance on multiple crops, averaging growing more than one crop variety for each crop species growing.

However, access to communal land resources for pasture and other agricultural activities was low, where only 17 percent of all farmers had access to communal agricultural land and 23 percent had access to pasture land, thereby presenting a point of intervention, as also the priority ranking clearly shows (land access ranks first place accessing a larger extension of land for farmers would have a positive effect on income).

Agroecological farmers were observed to have a significantly higher degree of *spatial and temporal heterogeneity* ($p<0.01$). Agroecological farmers had a more diverse mix of crops also in terms of spatial distribution as well as a higher temporal heterogeneity on their farm system, due to the use of land management practises such as crop rotation, terracing and wind-breaking. Heterogeneity in landscapes also provides more diverse habitats and fosters diversity of plant and animal species which benefit from dynamic relationships and provide ecosystem services, creating a more resilient agrosystem against climatic changes.

Statistical differences were observed for the *coupled with local and natural capital* indicator due to differences observed in the land management practises between the agroecological and non-agroecological farmers. External input substitution was evident among the agroecological farmers as 50 percent of the agroecological farmers relied on natural fertilizers compared to 18 percent of non-agroecological farmers while for synthetic pesticides, only 30 percent of the agroecological farmers used them compared to 45 percent of the non-agroecological farmers.

Nonetheless, all farmers still expressed the strong need to have more guidance and assistance to produce their own top dressing and biopesticides to wean off their reliance on external inputs. Farmers in the drier AEZ zones also expressed the strong need for infrastructure, such as irrigation or access to groundwater resources, to enable continued harvest in the face of rainfall variability. In these dry areas, water seemed to be an extremely limiting factor, in particular in this year of below-average rainfall. Fair and sustainable irrigation schemes would be needed, however, water shouldn't be sourced from river sources and thereby triggering water conflicts downstream, as happening now.

Significant differences were observed between the two farm systems for the *reflective and shared learning* indicator ($p<0.01$) as the agroecological farmers were observed to have higher participation in AP/FFS groups and better access to extension services availed by NGOs.

Agroecological farmers scored significantly higher in the *honour's legacy* indicator ($p<0.01$). At the sub-indicator level, agroecological farmers were observed to have a higher integration of tree products for agricultural production as well as anthropogenic use. Due to the transfer of traditional knowledge through their associative groups, the farmers were more likely to use trees for natural remedies, pesticide and soil fertilizer.

Some of the limitations and vulnerabilities according to the farmer's priority ranking, include low access to communal land resources, financial services and insurance for both farmer groups.

4.2.4 Social dimension case study: perception of farmer communities

To complement the findings from the SHARP survey, we provide additional information on the farmer's and farmer communities' perception of climatic change and their main coping strategies. The information is based on a participatory mapping exercise conducted by ICE (Mburu, n.d.). Participatory mapping is a simple visual tool used to engage the community in thinking about their ecosystem and building a common understanding, laying the foundation for improved community-based governance of natural resources.

Methodology

The mapping involved 120 community members who comprise the eight communities that live along the Kathita River, the same area as the SHARP assessments took place. Assembled in groups, they were asked to come up with three maps: that of the past to reflect on tradition, the present to highlight the current challenges and their vision of the future in an ideal scenario (see **Annex 4**). They were led by the elders who are custodians of knowledge, especially in drawing the map of the past. These three maps help engage the community in critical thinking about the environmental changes and challenges facing them. They probed the elders that came before them for the map of the past; and probed each other on what they visualized as being the map of the future.

In order to put this mapping into a climate perspective for the current study, the main facilitators of the participatory mapping in 2014 were gathered in an extra climate FGD. The questions asked, were extracted and adapted from Valdivia-Díaz *et al.* (forthcoming).

Results

The main insight of the exercise was the stark contrast between the maps and calendars of the past and those of the present. The map of the present reflected the reality of the destruction of ecosystem habitats that have happened over time, and all participants agreed that the river is faced with a serious threat of running out of water. Using the map of the future, they envisioned a future in which the river would undergo restoration back to a state analogous to the map of the past.

However, the group highlighted possible tensions, especially with landowners who may view the restorative activities as trespass on their farms. They also identified the possibility of resistance by farmers who are flouting existing water abstraction guidelines as well as those who have installed illegal abstraction points.

The degradation of Kathita River begun with land adjudication when sacred sites were allocated to individuals instead of being designated as community land. Under such circumstances, community members would be denied access to such sacred sites for their rituals, which made the sites weak. This also weakened the traditional ecological law, which could not be enforced by the custodians on private property. The landowners then failed to protect the riparian reserves and opened their land to the banks of the river for agriculture and grazing, exposing the banks to severe soil erosion. The community also identified the weakened traditional initiation and the clan governance system as the main culprits in differential integration of youth into the system for the subsequent protection of sacred sites. Also, The Water Resources Management Authority failed to enforce and enhance the policy guidelines on the abstraction of water from the Kathita. Many illegal abstraction points were installed and those which are legal are not following the laid down regulations. The combined impacts of these failures have caused a significant reduction of river water volumes increasing making the whole system more vulnerable to climatic changes.

The climate FGD then stressed the prolonged drought that has persisted from 2018 to date, probably linked to climate change, which caused the complete failure of harvest for two years in a row in some parts. The discussion, affirming again that while all areas are affected by climatic shocks, protected and reforested areas like riverines and forests have retained some level of resilience against climate change-induced drought since they manage to keep a good level of moisture. (This is because they are in the valleys where the water converges, the water table is high and the trees work as hydraulic pumps). Further, some of the present soils are not very vulnerable to erosion due to good protective vegetation cover and consequently have a higher water storage capacity. However, due to the overgrazing of other parts, agropastoralists tend to take their animals for grazing along the riverine, increasing pressure on these sites, resulting in degradation and pollution. Overgrazing in the uplands also threatens the rivers through contamination and increased erosion.

The mapping clearly shows that these communities' livelihoods strongly depend on ecosystem services. In particular, provision of (clean) water, medicinal herbs, building materials, fuelwood, grazing resources, pollination, and natural healing (traditional medicine prescribes going to the forest). However, these services are threatened and in particular soil erosion is rampant due to steep areas being overcultivated or overgrazed. To tackle the root causes threatening the very foundation of their livelihoods, community conservation groups are spearheading the following measures to achieve their vision of the map of the future.

First of all, the reforestation of degraded forests, riverine and communal lands is deemed essential by the communities that are planting species like *Senna Siamea, Melia Volkensii, Azadiracta Indica* to control erosion. Further, they are terracing, making stone lines and trash lines out of crop residues to facilitate infiltration and minimize run-off of rainwater. Also key is that elders are re-establishing local resource governance, by reviving rituals to prevent unauthorised access and extraction of timber, sand and charcoal burning from sacred natural sites. A key outcome of the mapping exercise was the formation of a Coalition of Custodians, which was meant to consolidate and amplify the participant's voice in campaigning for the protection and recognition of Kathita River as a sacred river.

Conclusions

The comparison of the past and present maps shows the stark degradation of the ecosystems and the reduced ecosystem service provision over the last decades. The climate FGD stressed that the region has been affected by climatic shocks and continuous drought, but the protected areas like riverine and forests have retained an increased level of resilience. To achieve their visionary map of the future, lead communities and the partner organisation ICE came to the clear conclusion, "that only integrated agroecological measures can bridge the gap between these two maps" ('Eco-Cultural Mapping Workshop Tharaka , Kenya', 2011).

To tackle the root causes threatening the very foundation of their livelihood, community conservation groups need to push for agroecological measures which are very much in line with FAO's Global Knowledge Product (GKP), tend to ameliorate the five capitals of the sustainable livelihood framework and are determinants of the adaptive capacity as defined by the IPCC (**Chapter 1.3**). As the expected threats of climate change for Kenya include more frequent temporary droughts, the community approach of applying agroecological practices, in particular SLM measures, reforestation as well as diversification (e.g. beekeeping), has shown to have the potential to increase the communities' resilience to face these challenges. Achieving this transformation and closing the knowledge gap towards integrated agroecology needs external facilitation and support, due to lack of finance and knowledge, as well as political support to improve resource governance.

4.3 RESULTS CASE STUDY SENEGAL

4.3.1 Context Senegal

Senegal's climate is characterized by a rainy season which duration gradually decreases towards the north (June-October in the south, July-September in the north) and a dry season (generally November-June). The temperature drops a little below 16°C in winter but is often above 40°C in summer. The country is subject to the influence of the maritime trade winds and Harmattan in the dry season. The average rainfall on the territory is 687 mm/year. El Niño events are associated with drier conditions in the Sahel, La Niña decreases temperatures (FAO, 2005b; McSweeney, New and Lizcano, 2010). The following climatic regimes can be found in Senegal: semi-arid (BSh), arid (BWh) and tropical savannah (Aw), with developed biomes of grass savannah, tropical rainforest and tree savannah. Regions with a structural precipitation deficit are defined as arid zones with less than 50mm annual rainfall. Semi-arid climates receive less precipitation than potential evapotranspiration.

Senegal is divided into six major agroecological zones (we highlight in particular two of them which will be part of the technical potential analysis, Niayes and Eastern Senegal).

TABLE 7.

SENEGAL´S AGROECOLOGICAL ZONES AND THEIR CHARACTERISTICS

The Senegal River Valley	Strip of about 15 km, composed of a series of alluvial plains and sandy highlands, it covers part of the Saint-Louis and Matam regions.
The silvopastoral zone	Located to the south of the Senegal River Valley, it is the country's main livestock region. Rainfall is very low. Forage resources are scarce and severely degraded.
The Niayes area	Covering a strip of 5 to 10 km along the Atlantic coast, this area has a high population concentration and is the main horticultural region in the country. It is challenged by urbanization, and also by land tenure and water-related issues.
The groundnut basin	Composed in its northern part by the regions of Thies, Diourbel and (partially) Louga and in its southern part by the regions of Fatick, Kaolack and Kaffrine, this basin has suffered from severe droughts in recent decades. Ecosystems have been degraded and soil fertility has severely declined. The groundnut crisis (2002/2003) has exacerbated the region's difficulties.
Casamance	Country's zone that benefits from abundant rainfall. There is diversified traditional agriculture: rainfed rice, fruit production, cereals, cotton (in Upper Casamance).
Eastern Senegal	It includes the regions of Tambacounda (where Koussanar is located) and Kedougou. It is a cotton and cereal producing in front of area.

Seventy percent of Senegal's population work in the agricultural sector, resulting in 17 percent of the GDP. While forests cover about 43.8 percent, agriculture covers about 46 percent of the area of which more than 17 percent is arable. Agriculture in Senegal is largely dominated by very small family farms (occupying 95 percent of the country's agricultural land, representing 80 percent of the country's population), that depend on traditional rainfed agriculture and activity which represents all village agricultural activities. Pastoral systems and polyculture systems can be found respectively in rainfed and irrigated farming areas (although less than five percent of the agricultural land is irrigated). Next to multi-purpose family agriculture, a commercial type of agriculture is emerging as well. These farms are located in the peri-urban area of Dakar, in the Niayes area, where they are dedicated to horticulture and intensive livestock farming. They are also beginning to appear in the Senegal River delta area in irrigated areas. However, their share in agricultural production and exports is still low, with the exception of the horticultural and poultry sectors. They employ one percent of the working population and control five percent of agricultural land.

Agriculture is based on both cash crops (groundnuts - 21 percent, cotton and in part horticultural products) and food crops (mainly cereals and millet - 20 percent). Livestock farming also plays an important role (29 percent), as does fishing. Still, the country must import nearly 70 percent of its food needs, mainly rice (main stable food, 65 percent of the country's consumption is imported), but also wheat and maize (CIAT/USAID, 2016). This dependence on global markets exposes households to price fluctuations and greater vulnerability (WFP, 2014).

Ranked 154th out of 186 countries on the Human Development Index (HDI) in 2013, food insecurity remains a constant concern in Senegal.

Challenges for agriculture and climate change impacts

Ensuring and improving food security and nutrition for vulnerable populations, despite the effects of climate change, is the key challenge today in Senegal. Agriculture and water resources are cited as the two most vulnerable sectors in the country's national determined contribution. According to the country's NDC, the projected climate change impacts focus particularly on rising temperatures (projected 0.2°C/decade) and decrease in rainfall, which would have devastating consequences on livelihoods and socio-economic activities. Climate change is already an undeniable reality for Senegal. In a report published on the state of the environment by the Ecological Monitoring Centre or *Centre de Suivi Écologique*, the following trends are noted:

- Mean annual temperature increased by 1.6°C since 1950 with a stronger observed increase in the north of Senegal, averaging 3°C. Temperatures will continue to increase by 1.1°C to 1.8°C by 2035, and up to 3°C by the 2060s. Warming is faster in the interior of the country than compared to the coastal areas.
- A 30 percent reduction in rainfall between 1950 and 2000, with a strong variability from one year to another and from region to region. While precipitation trends have improved since 2000, it does not necessarily signal an end to the dry cycle.
- Higher frequency is noted in flood events, particularly in the lower-lying areas of Dakar and north-western Senegal.
- Extreme droughts in 2002 and 2011 heightened food insecurity for over 200,000 and 800,000 people, respectively.
- Changes in the production of biomass, especially in the northern part of the country, reducing forage production for livestock activity (CIAT/USAID, 2016).
- The groundnut-millet rotation has traditionally been the dominant practice with more area devoted to groundnuts. However, in recent years, as groundnut yields have begun to decrease due to poor soil conditions and climatic factors, millet production has increased in acreage (CIAT/USAID, 2016).

In addition, and partly linked to climate change, agriculture in Senegal suffers from a lack of access to land and is negatively impacted by degradation of soils and of water resources (in quality and quantity), of forests and high use of synthetic pesticides (DyTAES, 2019). The Niayes, as peri-urban horticultural zone (studied further in the technical potential analysis in this report), is particularly impacted by these challenges.

4.3.2 Policy potential in Senegal

Introduction: relevance of agroecology in the context of climate change in Senegal

In Senegal, agroecology emerged in the 1980s, when negative environmental, human and animal health consequences became evident from agricultural chemical application. These challenges allowed agroecology to offer a promising solution to open up new horizons for future generations. Its evolution has been marked by the implementation of a multitude of local initiatives, mostly carried out by NGOs, farmers' organizations, some private sector and national level platforms (Touré and Sylla, 2019). For more than 30 years, focus was on integrated and sustainable land management, water and soil conservation practices, crop associations, biological control of plant pests, organic conservation methods for agricultural products and agroforestry (AgriSUD, 2010). Along the same lines, universities and research centres, such as the Cheikh Anta Diop University (UCAD), ISRA, the French Agricultural Research Centre for International Development (CIRAD), the *Institut National de Pédologie* (INP), and the *Institut de Recherche pour le Développement* (IRD), have long been involved in the creation and dissemination of knowledge, training of human resources, supervision of agricultural practices and promotion of products from healthy and sustainable agriculture. Various agroecology pilot projects have produced tangible effects at three levels within the society: at socio-economic level (consumer awareness on products' origin, promotion of healthy food and enhancing the local economy through short circuits markets); at environmental level (promotion of organic fertilizers, biocides); and at political level (public authorities have shown their interest in agroecology, as part of the political discourse and agenda) (Cissé, 2018).

The year 2019 has seen an acceleration of achievements, creating real momentum for agroecology:

- The Senegalese government placed agroecological transition among the five major initiatives of the Priority Action Plan of the second phase of the *Plan Sénégal Emergent* (2019-2024), the key national policy framework.
- Producer organisations, CSOs, research centers, consumers, local authorities and sectoral ministries have decided to join forces and create an umbrella initiative to co-create a policy document (through a participatory bottom-up process) to support the government's commitment and to move towards an effective agroecological transition. This unitary framework consolidates all the numerous existing platforms and initiatives and is called la *Dynamique sur la Transition Agroécologique au Sénégal* (DyTAES).

Building on thirty years of experience and learning, this current combination of national multi-stakeholder momentum and political commitment raises questions on the past, current and upcoming policy potential of agroecology in regard to the multiple challenges of climate change.

Research approach

The methodology used in this research combines a literature review, stakeholders' discussions and individual interviews with key different stakeholders. Stakeholder discussions took place mainly during the 28-29 May 2019 workshop organized by FAO in collaboration with ISRA and Enda Pronat. The desk research aimed to characterize the political and institutional environment in Senegal as the implementation basis for agricultural policies, and to assess the explicit or implicit recognition of agroecology in institutional mechanisms.

The assessment focused on the actors responsible for NDC implementation at the national level, the financing instruments for the agricultural sector as a necessary condition for the success of agroecological initiatives, and finally the involvement of actors in charge of developing climate change policies in the agricultural sector. The desk research focused on online documents, mainly from state institutions and civil society actors that are finalized or in effect institutional documents (laws, public policy documents, sectoral policy letters, final reports of national projects and programmes, conventions and treaties). To assess the quality and relevance of the documents, the sources for each search algorithm was diversified to ensure consistency among the results obtained.

In total, the research examined 57 public policy documents related to the theme of the analysis. In particular, it sought to assess the extent to which agroecology is embedded into policies, and the concepts used in documents as well as speeches related to agriculture and climate change in Senegal.

For that purpose, the grid of analysis used focused on the declinations of "agroecology" when the concept is mentioned in policy documents, with reference to the FAO ten elements on agroecology (FAO, 2018b). Finally, as this study was conducted concurrently with the local consultations with communities led by the DyTAES on the issue of agroecological transition, several actors involved in the different stages of the process were interviewed, providing an analysis of the enabling environment at the local level as well.

In addition a large number of people from different backgrounds were interviewed: members of NGOs, farmers' organizations, local authorities, government ministries, decentralized government departments, research institutions, associations, etc. These interviews were done through various site visits, FGDs (including discussions in farmlands), discussions in local gatherings, offices, and local product processing units.

Results and Analysis

POLICY ANGLE: ANALYSIS OF POLICIES IN SENEGAL

Senegal has not stood on the side-lines of the emergence of agricultural practices that were inspired by the strong scientific research ongoing and linked to the social movement at the international level. Initiatives have been ongoing and multiplying from the local to the national level since the 1980s by producer organizations and pioneering CSOs. These have gradually attracted the attention of the Senegalese authorities, who embraced the idea that agroecology can bring about many benefits to Senegal and to the achievement of more resilient and sustainable production systems.

At the first International Symposium on Agroecology for Food Security and Nutrition held at FAO headquarters in September 2014, Senegal's Minister of Agriculture referred to Senegal's position as being "responding to the international market but also to create an environmental legacy of high quality on the one hand. On the other hand, to manage the present while taking into account generational solidarity in agriculture". Adding that such an option should be supported by a "co-constructed, co-managed and co-evaluated agroecology approach".

In late 2018, the President of Senegal Son Excellence Macky Sall also announced at the end of his first term, through the Plan Senegal Emergent Vert, the importance for Senegal to achieve an ecological transition. This government commitment was further demonstrated after his re-election in 2019, by the implementation of a programme on "sustainable reforestation of the national territory" in the semi-arid zones of the country, in conjunction with local authorities. The appointment of M. Haïdar El Ali, strongly committed in environmental issues and former Senegalese Minister of the Environment, as Director General of the Senegalese Agency for Reforestation and the Great Green Wall (ASRGM) was yet another favourable element that mirrors the increasing government commitment and political will. Finally, the government flagged its support to the *Journees de l'Agroecologie* took place end of January 2020 in Dakar. The discourse of national authorities, at the highest level, thus reveals a plan to move towards an agroecological transition. However, effective implementation and institutionalisation will need to go through strategies, plans, policies and programmes.

Presence of agroecology in policies

While government commitment is increasingly visible, it still needs to be translated into policies to ensure a proper institutionalization. Indeed, among current policy instruments related to agriculture, climate change, natural resource management and to economic and social development, that are there today, are rarely specific references to agroecology. However, policies generally promote some of the principles and practices related to agroecology, in particular: reforestation; agroforestry; and organic and sustainable agriculture. These terms have emerged at different periods of time and differ in focus. They have appeared in policies with regards to environmental aspects in production systems, or in characteristics of the producers, of the food systems or even the modes of integration into the markets that they support. In this regard, two specific periods can be identified:

- In 1960-2000, which coincides with the creation of the UNFCCC in 1992 and the emergence of the COPs, the term "agroecology" does not appear explicitly in any public policies.
- In 2000-2012 the term "agroecology" appears only once in all public policy documents of the country. The document in question is the National Strategy for Agricultural and Rural Training (SNFAR) of 1999, updated in 2005.

Among the 21 public policy documents related to agriculture and climate change in Senegal, the terms "agro-ecological" and "agroecological" are used 64 and 9 times respectively. According to the surveys, the lack of consideration for agroecology is explained by the fact that the concept was still new and still little known in the policy-making arenas. Even if the concept is not explicitly recognized in the main programmes of the government, fundamental ideas underlying the agroecological principles are reflected in some documents, such as the protection and improvement of rural livelihoods, the promotion of equity and social well-being, and the good governance of natural resources.

The analysis and interviews further identify some policies and actions with negative externalities to the environment, which are not only incompatible with agroecology, but even hinder its possible up-scaling. These are in particular policies for the subsidization of synthetic fertilizers, the development of an intensive agriculture sector or an agro-industry oriented towards exports.

Since 2012, Senegalese authorities have advocated to accelerate the pace of work to achieve Senegal's growth. The *Plan Sénégal Emergent* (PSE), which is the main reference policy document for the government, has implemented plans, programmes and strategies for agricultural development viewing to make agriculture a lever for economic and social development. Out of these policy documents, 25 were analysed (see **Annex 1**). The lesson learned is that agroecology is not the subject of a specific policy, but its promotion and integration in national agricultural production systems are taken into account in the *Programme de l'Accélération de la Cadence de l'Agriculture Sénégalaise* (PRACAS, 2014), and the *Programme National d'Investissement Agricole pour la Sécurité Alimentaire et la Nutrition* (PNIASAN), (2018-2022).

Assessment of the integration of agroecology into public policies on agriculture and climate change

The increasing impacts of climate change have prompted actors to reflect on mechanisms of adaptation and resilience building, in particular in agricultural sectors as identified in the *Plan d'action national pour l'adaptation* (PANA) (République du Sénégal, 2006). As such, several policies were developed that tended to promote different actions aimed at reducing sensitivity and exposure of agriculture to climate risks without explicitly labelling them as agroecology, including the Agro-Sylvo-Pastoral Orientation Law (LOASP), PNIASAN, etc. In their development, these policy documents incorporate a holistic approach and ambitions that reflect the elements of agroecology, as defined by FAO (FAO, 2018b). These include aspects related to biodiversity conservation, the promotion of more intensive and sustainable agro-sylvo-pastoral production as well as the integration and diversification of production (MEDD, 2016).

The PNIASAN (2018-2022) is the only document which makes explicit reference to the concept of agroecology and its principles, linking it mainly to the objective of increasing and diversifying production. The programme promotes agro-sylvo-pastoral with the aim to address the following aspects: (i) developing production systems that respect the environment; (ii) ensuring the safety of food consumed; and (iii) improving the integration of agricultural/breeding, aquaculture and plant production systems.

Senegal's NDC, a key national document providing guidelines for action to address climate challenges, does not explicitly refer to agroecology. As recently brought forward by the IPCC, agroecology is a promising approach for sustainable land management (IPCC, 2019), thus the NDC highlights that SLM has significant potential as an adaptation measure. It further states that it is important to combine approaches and measures to strengthen the capacities of agro-silvo-pastoral producers to cope with climatic shocks and adapt to the threats of climate change. This will also help to improve food and nutritional security and increase incomes.

It is noteworthy to highlight that using synergies between multiple stakeholders is key for agroecology to be scaled up, since it is an interdisciplinary and multi-scaled approach. Policies fostering synergies between stakeholders to ensure optimal land management thus can support this. The National Strategic Investment Framework for Sustainable Land Management (NSIF/SLM) seeks to ensure synergy in the intervention of stakeholders who are encouraged to work together to reverse land degradation trends in a sustainable manner.

The analysis further investigated possible entry-points to scale-up the consideration of agroecology in existing laws and policies. This potential was found in the following two types of policies:

- **Laws and policies currently in favour of agroecology:** these are policies which integrate the principles of agroecology and create opportunities to integrate all relevant actors into the dynamics of agroecology. Those are the LOASP, the NSIF/SLM and the National Strategy for Sustainable Development (SNDD). Furthermore, Senegal's NDC already emphasizes various elements related to agroecology (in the context of production) such as SLM. The NDC also expresses needs and challenges related to the environmental and social aspects that agroecology can address. The 2020 NDC revision could, therefore, be a very interesting momentum to substantiate the integration of agroecology.

- **Partially incentive-based laws and policies:** these are policies which are "neutral" in their characteristics and could provide an entry-point to scale-up agroecology. This is the case with the Environment and Sustainable Development Sector Policy Letter (LPSEED), which aims mainly at combatting deforestation and land degradation. In addition, there is also the Agriculture Sector Development Policy Letter of the Ministry of Agriculture and Rural Development (LPSDA MAER), which envisages the reconstitution of seed capital, the intensification of agricultural production and the development of mechanization adapted to the local production systems.

Although there are selected favourable policies addressing the multi-dimensional challenges of climate change and although possible entry-points to scale-up agroecology exist, it is important to mention the key challenge that some laws and policies continue to be unfavourable to agroecology. They strongly undermine a possible scaling-up, in particular those promoting intensive systems, the unsustainable use of chemical fertilizers and synthetic herbicides, the promotion of monoculture, as well as others related to access to land and seeds. On example is the protection of peasant seeds from seed industries. Regarding the latter, even if Senegal ratifies the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), which technically guarantees these rights to farmers, peasant seeds are not yet recognized in national legislation (APBREBES, 2019).

POLITICS ANGLE: ANALYSIS OF HOW AGROECOLOGY IS PERCEIVED IN SENEGAL

The analysis reveals the challenge of translating the interdisciplinary nature of agroecology in policies but also to understand its holistic and systemic nature and achieve a common vision and understanding. This leads to different views and positions about the concept. Indeed, while CSOs see agroecology as a "societal project", a "social transformation" (DyTAES, 2019), it seems that most of the government-led initiatives relate more to forestry programmes, focusing mostly on production, and the two agroecology principles of resource-efficiency and resilience. Also the scope differs among stakeholders. Civil society organizations, research organizations and producer organizations understand agroecology to be interdisciplinary and encompassing the entire food system, "from seeds to waste treatment while others see it in discreet terms which still put emphasis on individual sectors" as one interviewee argues.

Interviewees mentioned that the current focus of policies is often on maximizing the production, focusing on two of the four pillars of FSN: availability and stability. As highlighted by the recent HLPE report (HLPE, 2019), agroecological approaches contribute rather to the two other pillars of FSN, such as access and utilization, highlighting participation and empowerment-related elements. This production-oriented focus can be explained by the double challenge of a) the need to feed a continuously growing population, and b) the lack of conclusive evidence on the ability of agroecology to produce the same quantities of food within the same time-frame as conventional agriculture, while also protecting natural resources and biodiversity.

Stakeholders interviewed during the local consultation workshops understand agroecology as an approach revaluing diversity and human values, enabling the co-creation and sharing of scientific and local knowledge, focusing on effectiveness, efficiency and drawing out priority on responsibility in the governance of natural resources. Many highlight the need to reconsider and ensure the consistency of policies and legislation in various fields, including land, energy, spatial planning, market regulation, agricultural research, youth education, engineering training, etc.

The absence of both a clear and jointly agreed definition and a national reference document containing a common vision of the government and its partners on agroecology, contributes to keeping it out of the policy-making realm. The compartmentalization of decision-making spheres between the various sectoral ministries brings an additional layer of difficulty.

The challenges to a unitary understanding of agroecology are identified as follows:

- National priorities translated in policies seem to be more oriented towards maximum production, with no strong priority made on environmental issues. The idea of generating economic gains through exports without any consideration of environmental sustainability is often mentioned in the discourses and thus relegating alternative options such as agroecology.
- The concept of agroecology is seen as relatively new and is still the subject of much confusion, particularly because of many other concepts in parallel, particularly: "organic farming" in the 1980s, "sustainable agriculture" in late 1990s, "healthy and sustainable agriculture" in the early 2000s.
- The absence of a common understanding of the holistic principles of agroecology, hindering the translation into a political vision.
- The lack of awareness of and capacity to engage with agroecology.
- The lack of a common framework among stakeholders for formulating policy proposals building on agroecology elements. In this context there is also a low level of involvement of agricultural research organizations at the national level and therefore the lack of evidence of the economic, social and environmental viability of agroecology. This should soon evolve with the recently launched DyTAES in Senegal.
- The absence or weakness of social demand by consumer associations due to their lack of resources for communication and interaction with the general population.
- External pressure and lobbying actors that promote the use of synthetic fertilizers and other practices which are opposed to agroecology.

POLITY ANGLE: INSTITUTIONAL FRAMEWORK AND COORDINATION MECHANISM IN SENEGAL

The issue of climate change in agriculture has a multi-sectoral dimension requiring strong synergies, increased collaboration, effective coordination mechanisms and the inclusive participation of all actors involved in state processes, to create a policy environment conducive to scaling up agroecology.

The current institutional framework and mechanisms for coordinating the processes, design and implementing agricultural policies and strategies bring together various actors. These are: the office of the President of the Republic; the National Assembly; the Economic, Social and Environmental Council (ESEC), the Ministry of the Environment and Sustainable Development (MEDD), the Ministry of Agriculture and Rural Development (MAER), the CSE, the Comité National sur les Changements Climatiques (COMNACC), the Direction de l'Environnement et des Établissements Classés (DEEC), the Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM) and the Collectivités Territoriales (CT). Also, other non-governmental actors are involved such as members of civil society, local consultation frameworks, technical and financial partners, customary authorities and religious leaders, universities and research institutes, etc. These stakeholders operate with very different levels of involvement, but remain complementary to each other in addressing the climate challenge in the agricultural sector.

Two categories of stakeholders can be distinguished (see table 8 below): (i) those already involved in agroecology and climate change policy development processes; and (ii) those not yet involved, and barriers to overcome to successfully involve them.

TABLE 8.

STAKEHOLDERS INVOLVED (LIGHT GREEN) AND CURRENTLY NOT INVOLVED (WHITE) IN AGROECOLOGY-RELATED ISSUES

ENTITY	STRUCTURE	ROLE FOR THOSE INVOLVED / CHALLENGES TO OVERCOME FOR THOSE NOT INVOLVED
State	Ministry of Environment Division taking care of water resources and forestry	Elaborating and managing agroforestry and climate change-related projects Managing the NDC
	Division taking care of climate change-related issues	Information and training of state institutions for climate change adaptation Advice and support from the on climate change issues
	Ministry of Agriculture Changements Climatiques et Agriculture Sénégalaise (CCASA), a national science policy dialogue platform for adaptation to climate change	Management of the support programme for the creation of green jobs
	Green Financing and Partnerships Branch	Management of climate funds, implementation of projects and programmes
	Centre de Suivi Ecologique (CSE)	Awareness-raising is missing
	Some sectorial Ministries (livestock, agribusiness, other departments of agriculture and environment, etc.)	Lack of understanding of the potentials of agroecology
	Strategic Direction Office of the *Plan Sénégal Emergent* (BOS/PSE)	Lack of awareness
	National Assembly	Lack of awareness
	Social and Environmental Economic Council (CESE)	Lack of awareness
	High Council of Territorial Communities HCTT)	Lack of awareness
	Rural Development Support Fund	Lack of awareness
Civil Society	Non-governmental organizations (NGOs)	Developing initiatives, advocacy work, communication
	Producer (livestock and fisheries) organizations	Facilitation, promotion of good practices, promotion of local know-how, marketing
	Fédération Nationale pour l'Agriculture Biologique (FENAB)	Production of a strategic and prospective note in favour of agroecology
	Associations and individual consumers	Lack of communication, information and awareness
	Conseil national de concertation et de coopération des ruraux (CNCR)	Lack of communication, information and awareness
	Media / Opinion leaders	Lack of communication, information and awareness
Research and Academia	ISRA / Center for the Development of Horticulture (CDH) / *Bureau d'analyses macro-économiques* (BAME) CIRAD UCAD	Experimentation, training, provision of documented scientific and technical evidence, innovation
	Global Green Growth Institute (GGGI)	Development of strategies around green growth
	Advanced Education	Training of managers: lack of communication, information and awareness
	Basic education (national education)	Lack of communication, information and awareness
Collectivités territoriales	Local elected officials and grassroots communities	Support/promotion
	Consumers	Demand for quality products
	Associations of Mayors of Senegal (AMS)	Absence of institutionalisation
	Grassroots communities	Lack of communication, information and awareness
Private sector	Agroecology input suppliers	Production and marketing
	Non-agroecology input suppliers	Actors to raise awareness of the agro-ecological approach
	Various businesses	Lack of communication, information and awareness
Banks and Insurance companies	Microfinance institutions and banks	Lack of communication, information and awareness
	Agricultural insurance	

To grasp the interdisciplinarity of agroecology, many stakeholders highlight the need to set up a coordination mechanism. Based on a cross-cutting and transversal approach, the resource persons suggested to link the different dimensions of agroecology through a coordination mechanism in order to overcome the fragmentation challenges. Others have recommended establishing a new coordination mechanism linked to the agroecological and climate change policy development process. Such a coordination mechanism should be multi-sectoral, multistakeholder and supported politically (led by a government ministry). Interventions related to agriculture and adaptation policies are in the government's responsibility. However the analysis highlights that in the case of agroecology rather CSOs, research and development partners are those driving the major dynamics, strongly committed to supporting the search for innovative alternatives to the climate challenge.

To respond to this need for a coordination mechanism, the establishment of the *Dynamique pour une Transition Agroécologique au Sénégal* (DyTAES) in 2019 now offers a unitary framework for multi-stakeholder exchanges on agroecology on a national level. The aim of the framework is to tackle both, the challenge of the multiplicity and fragmentation of existing initiatives and platforms (e.g. 3AO, TAFAE, AEB), as well as the lack of coordinated action and unified advocacy work.

DyTAES brings together all stakeholders: producer organisations, CSOs, research, consumers, local authorities and sectoral ministries. This dynamic aims at stimulating political dialogue on the agroecological transition through comprehensive consultation rounds with stakeholders at different levels: between August and October 2019, local consultations took place in the six agroecological zones in Senegal. In a participatory and bottom-up approach this process aimed at: (1) drawing out a diagnosis of the challenges regarding agricultural development in general; (2) raising awareness on the agroecological transition; (3) identifying local initiatives on agroecology, collect best practices taking place on the ground; (4) identifying specific challenges and levers for agroecology; and (5) drawing out recommendations. About one thousand local stakeholders participated throughout these six consultations. An additional consultation took place in Dakar, targeting consumers and consumer's organizations.

Building on the results of these local consultations, and thus on grassroot concerns, the current key objective is to co-create a contribution document to anchor the agroecological transition in national policies. The very first official national workshop by DyTAES took place in November 2019, with the objective of presenting the results of these local consultations and working towards the contribution document. It gathered more than 100 participants from different backgrounds (research, CSOs and government representatives) and levels (local, national and international actors). Among the government representatives present, in particular were: some mayors (the Ndiob Mayor, renowned promoter of agroecology, who was distinguished by a price delivered by FAO in 2018), the CSE, and a Deputy from the National Assembly in charge of local consumption. The Technical Adviser number two of the Minister of Agriculture gave a keynote speech as well.

Throughout this process, the media played a crucial part as they disseminated information to the broader audience following the local consultations. A video on DyTAES was also produced, so as to ensure visibility and common understanding of the dynamic (for more information please see: https://www.endapronat.org/dytaes/).

DyTAES paves out a way on how promoters of agroecology work, from "opposition power" for more than 20 years, to a strong unified "proposing power" today, stimulated by the growing institutional commitment. The key idea is to build proposals stemming from a participative consultation process at the local level and draw out how these can be promoted and inserted throughout the lines of existing policy frameworks. The resulting political recommendations were handed over to the government during the *Journees de l'Agroecologie* in early 2020 in Dakar, Senegal.

IDEAL SCENARIO FOR A TRUE AGROECOLOGICAL TRANSITION IN SENEGAL

After more than 30 years of existing initiatives, 2019 seems to have been the year sowing the seeds for a turning point on the enabling environment and the institutionalisation of agroecology in Senegal. Indeed, the combination of an increasing institutional commitment with a strong national multi-stakeholder dynamic (speaking in a unified voice, ensuring cohesion in the existing initiatives and platforms), is a promising milestone towards an agroecological transition in Senegal.

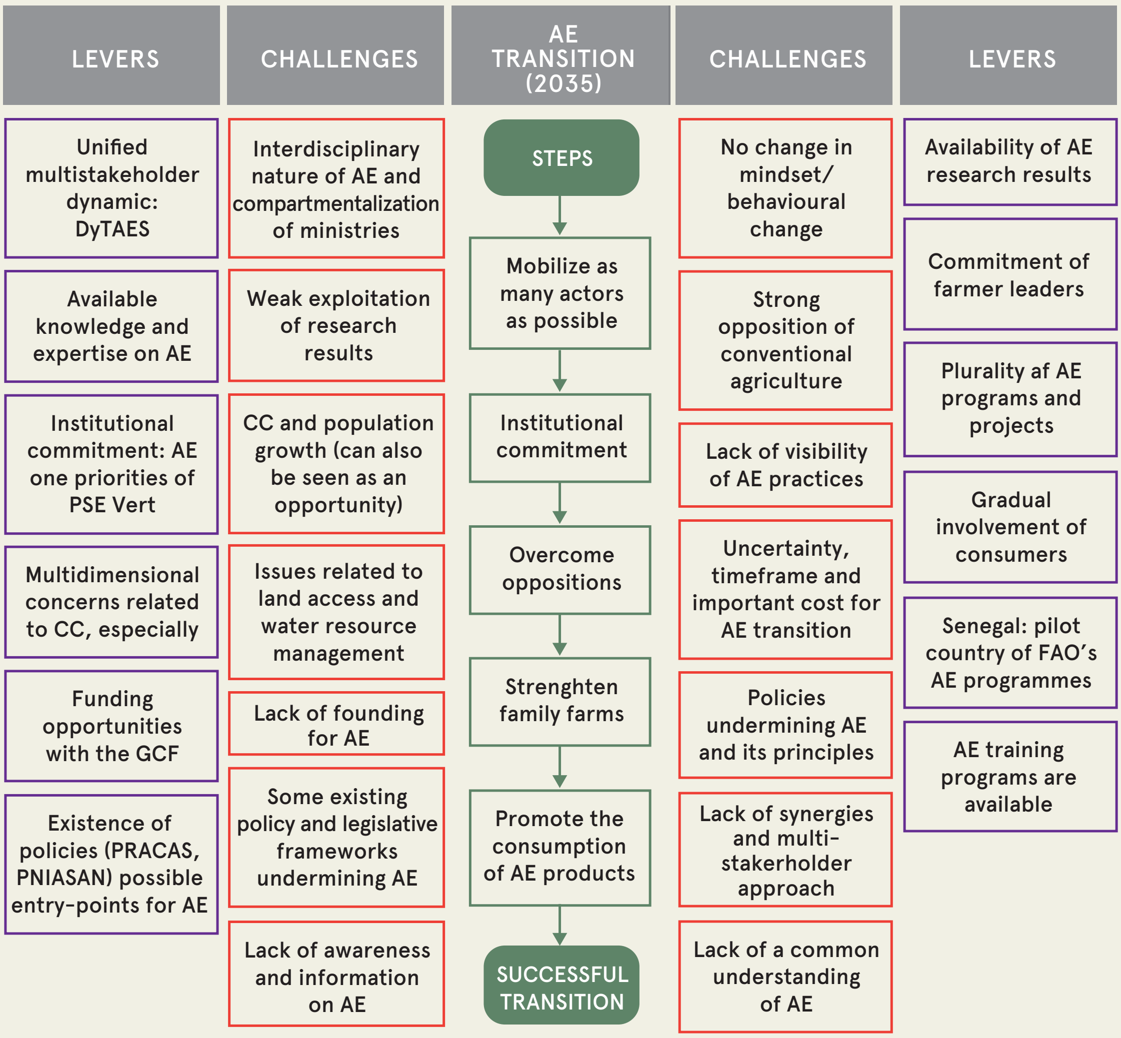
So what would a vision for an agroecological transition in Senegal and its preliminary roadmap for 2035 look like? The stakeholders interviewed were unanimous of the fact that the development of agroecology presupposes a supportive government, which guides its decisions based on the elements of agroecology. This requires a transformational change with regard to current conventional agriculture and sharing a common understanding and vision among all stakeholders.

The ongoing dynamic, in particular through DyTAES, can positively contribute to a redefinition of the government's conceptions of agroecology and a refocusing of priorities by 2035. The steps to be taken are multiple: (i) build a common understanding and vision around agroecology; (ii) build a unified advocacy framework bringing all actors together, based on scientific evidence validating the benefits of agroecological systems; (iii) give greater visibility to agroecological initiatives; and (iv) clearly distribute the roles to the different stakeholders.

Figure 23 summarizes the findings from the participative diagnosis and interviews, highlighting the different milestones, challenges and levers for an ideal agroecological transition in Senegal.

FIGURE 23.

AGROECOLOGY TRANSITION (2035), CHALLENGES AND LEVERS*



** AE=agroecology, CC=climate change, PSE = Plan Sénégal émergent, PRACAS = Programme d'accélération de la cadence de l'agriculture sénégalaise, PNIASAN = Programme National d'Investissement Agricole pour la Sécurité Alimentaire et Nutrition.*

The ideal scenario for an effective agroecological transition does not seem unrealistic. Change is happening now in Senegal, even quite at a high pace. Differences and progress can already be noticed between May and November 2019. As an example, some stakeholders which were noted not involved in agroecology-related processes before, have been targeted in the meantime and were present at the first official 18-19 November national workshop organized by DyTAES. This includes the association of consumers, a deputy of the National Assembly, the CNCR, the CESE, the media and the Mayor of Ndiob.

Overall political potential: conclusions and recommendations

After more than 30 years of multiplying initiatives, platforms, mobilizing a wide range of stakeholders from producer organizations to CSOs, researchers and so on, 2019 appears to have been the year sowing the seeds for change and for a promising agroecological transition.

Although agroecology and its principles do not yet appear fully in policy frameworks, not ensuring yet an enabling environment for the scaling-up of agroecology, a certain institutional commitment can be observed now and it is increasing. In 2019, the Senegalese government placed the agroecological transition among the five major initiatives of the Priority Action Plan of the second phase of the Emerging Senegal Plan (2019-2024).

In parallel, the concern of the multiplicity and fragmentation of initiatives, platforms advocating and working on agroecology was overcome through the establishment of the umbrella initiative DyTAES. Aiming at gathering all stakeholders in a unified framework and establishing coherence among the initiatives, the DyTAES also aims at accompanying the increasing institutional commitment with strong proposals to ensure a meaningful and sustained agroecological transition. Local consultations followed by a multistakeholder national workshop have resulted in a contribution document proposing concrete steps to ensure a transition. This contribution document was handed to the government in early 2020.

Thus, the institutionalisation of agroecology seems promising, although with remaining key challenges to overcome, in particular related to existing policies undermining any agroecological transition but also the lack of awareness, communication and knowledge on agroecology and the lack of scientifically-supported evidence translated into policy and strategies.

Building on these findings, the following recommendations are suggested:

- Consolidate the current multi-stakeholder dynamics and strengthen the DyTAES framework harmonizing existing platforms and interventions working on agroecology in order to build a common vision and unify advocacy efforts.
- Ensure and work towards a common understanding of agroecology and its potential to build resilience to climate change so as to translate it into a policy vision.
- Carry out awareness-raising activities to strengthen the strategic dimensions and ensure the institutionalization of agroecology.
- Strengthen scientific research to produce evidence about the climate performance and benefits of agroecology.
- Disseminate scientific results to a wide audience, communicate about agroecology and its potentials and strengthen the media coverage.
- Advocate for agroecology at the sub-regional level to influence community decisions that have an impact on national development strategies.
- Promote a revision of the legislative framework to ensure the integration of agroecology into policy strategies and field interventions.

4.3.3 Technical potential in Senegal

Methodology

Defining Agroecological Systems for the Senegalese Context

The choice of the sites for the study builds on the following elements:

1. target areas where there are family farms that have been in agroecological transition for several years and have adopted a variety of agroecology practices;
2. have representative areas of Senegal (rain-fed); and
3. have at least one irrigated area where agriculture is practiced throughout the year.

It also considers the four following criteria:

- Criterion 1: Exposure to climate variability (perceived climate change impacts, past climate shocks, etc.).
- Criterion 2: Presence of a control group (agroecology versus non-agroecology).
- Criterion 3: Mixed systems, polyculture-livestock systems.
- Criterion 4: Availability of historical climatic data.

Specificities of each of these two selected sites

Zone 1 – Niayes (four municipalities: Bargny, Keur Moussa, Diender and Cayar): there is a strong concern for the future of this vegetable producing area. Indeed, it supplies large cities with horticultural products, but faces today food security challenges, economic, political (land-use planning) and climatic (low rainfall and high pressure on groundwater by various users, which leads to a decline in the water table) and environmental (pollution from the uncontrolled use of agro-chemicals, such as synthetic fertilizers and pesticides) issues. Agriculture is much diversified in this zone, with a predominance of mainly high-value horticultural crops including onions, aubergines and cabbages, etc.

One finds there (1) small individual farms, operating on the basis of rental or sharecropping contracts and whose diversified produce are intended to supply the local market, but also (2) large and potentially specialized agricultural companies for which the products are intended for export markets (Touré and Seck, 2005). A wide range of family farms, with varying degrees of performance, find themselves between these two typologies.

The family farms supported by Enda Pronat in their agroecological transition with a focus on the supply of organic manure and phytosanitary treatment based on biopesticides, are found in the communes of Cayar, Diender and Keur Moussa. There are different farmer profiles in this area: women with very diversified small plots, men who integrate arboriculture and vegetable production, but also onion monocultures in irrigated systems (drip irrigation).

Zone 2 – Koussanar (Sénégal Oriental): Koussanar is a municipality located in the Eastern agroecological region of Senegal, characterized by farms with a predominance of grain crops (groundnut, millet and sorghum) produced under rain fed systems and with strong livestock-crop integration. Enda Pronat has been supporting 18 family farms over the past four years in the agroecological transition (organic fertilization, assisted natural regeneration, early planting with adapted seeds, etc.).

Sampling design

The sampling approach was based on spatial distribution and random sampling of farmers. In each of the two sites (Niayes and Koussanar), about 40 producers (**Table 9**) were targeted on the basis of the knowledge of Enda Pronat and ISRA.

Among these 40 producers:

- 34 were selected as “agroecological” (later labelled as “AE”).
- 51 were "control group" and selected on the basis of experience and knowledge of the environment by the Enda Pronat and ISRA field teams. These producers generally apply excessive quantities of pesticides

and synthetic fertilizers in an intensive production system, characterized by a monoculture. The lack of knowledge of the exact agroecological transition level of farms considered non-agroecological could lead to biases in results. Indeed, a farm that is considered non-agroecological may actually be in transition and therefore not really correspond to what is expected to be the characteristics of the control group.

TABLE 9.

NUMBER OF FARMERS SAMPLED IN 2 AGRO-ECOLOGICAL ZONES IN SENEGAL

ZONE	CHARACTERISTICS OF THE ZONES	NO. OF FARMERS FOR EACH ZONE	CONTROL GROUP
	Yearly rainfall (mm)	AE	
Niayes	400	14	31
Koussanar	700	20	20
Total		34	51

Data was collected by trained enumerators between July and August 2019 throughout interviews with the producers, using the structured SHARP survey developed by FAO, deployed in tablets SAMSUNG Galaxy Tab A.

OVERALL FINDINGS OF THE SELF-EVALUATION AND HOLISTIC ASSESSMENT OF CLIMATE RESILIENCE OF FARMERS AND PASTORALISTS (SHARP) RESILIENCE ASSESSMENT

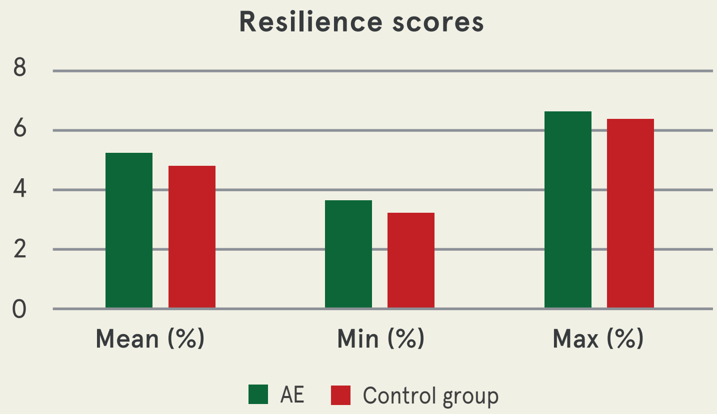
There are interesting differences between the two zones with regard to their resilience level as assessed in SHARP, according to each of their specificities. Therefore, we firstly discuss the overall resilience level of combined agroecological farms from both zones and then look at each zone separately.

The mean resilience scores of the agroecological farms was 5.2 while that of the control group was 4.8. As per the SHARP assessment, these mean scores are characteristic of systems that are mid-level climate resilience. This implies that both groups of farmers have certain abilities and capacities to withstand unexpected climatic shocks and climate variability.

There was no statistical difference between the overall resilience scores of agroecological and control group though agroecological farms had higher mean scores (**Figure 24** and **Figure 25**).

FIGURE 24.

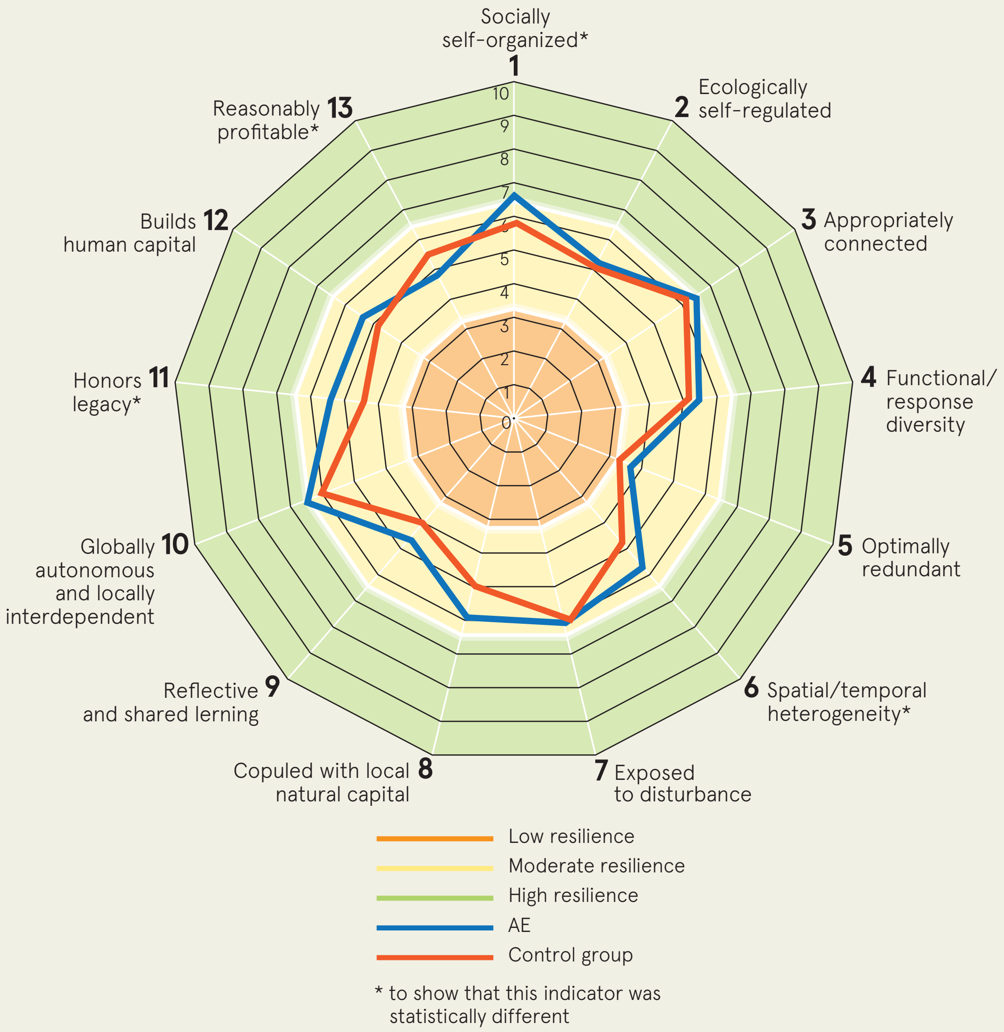
AVERAGE RESILIENCE SCORES OF AGROECOLOGICAL AND CONTROL GROUP FARM SYSTEMS



For AE, n=34 while for control group, n=51.

FIGURE 25.

AVERAGE LEVELS SCORES OF AGROECOLOGICAL AND CONTROL GROUP SYSTEMS BY AGRO-ECOSYSTEM INDICATOR AND LEVEL OF RESILIENCE



*NB: Significant differences were observed in 4 of 13 the resilience indicators determined by t-test and indicated as *p<0.05, ** p<0.01. Agroecological mean scores are higher compared to the control group for 3 of the resilience indicators that are statistically different, while control group is higher in one mean score.*

Though there was no statistical difference on the overall means of resilience between the agroecological and the control group, a statistical difference was observed for some resilience indicators between these two groups. Significant statistical differences between agroecological farms and the control group were observed in four out of the 13 indicators (**Figure 26**).

The scores of agroecological farmers were higher than those of the control group for three of these four indicators ("socially self-organized"; "spatial and temporal heterogeneity", "honours legacy") and lower for one of the indicators, the "reasonably profitable" indicator.

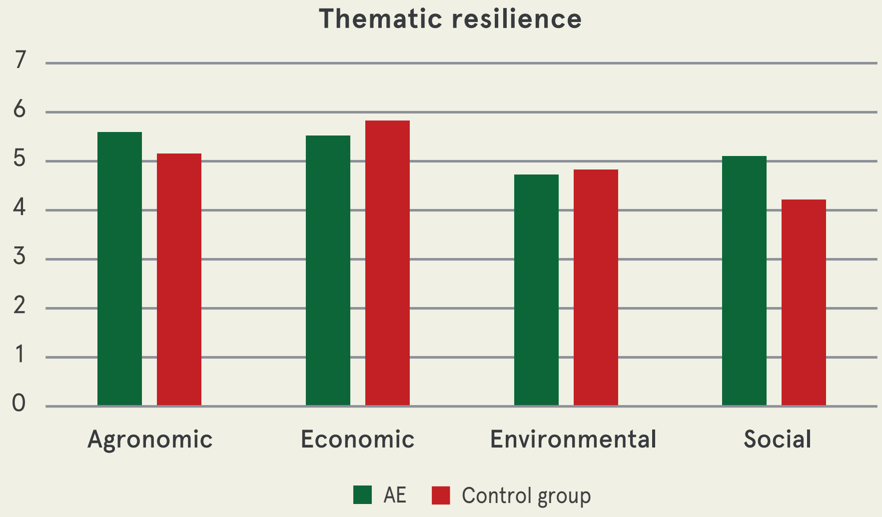
At the module level, significant differences in average scores were observed for 11 out of the 35 modules. Agroecological systems having higher average scores for 8 out of these 11 modules (all the three statistically different ones of the agronomic domain modules; two out of the four of the economic; none from the environment one; all the three of the social domain modules).

Domain results

SHARP results were also assessed for each of the four areas (agronomic practices, environmental aspects, social interactions and economic components), as shown in **Figure 26**.

FIGURE 26.

AVERAGE TECHNICAL SCORES FOR THE FOUR DOMAINS



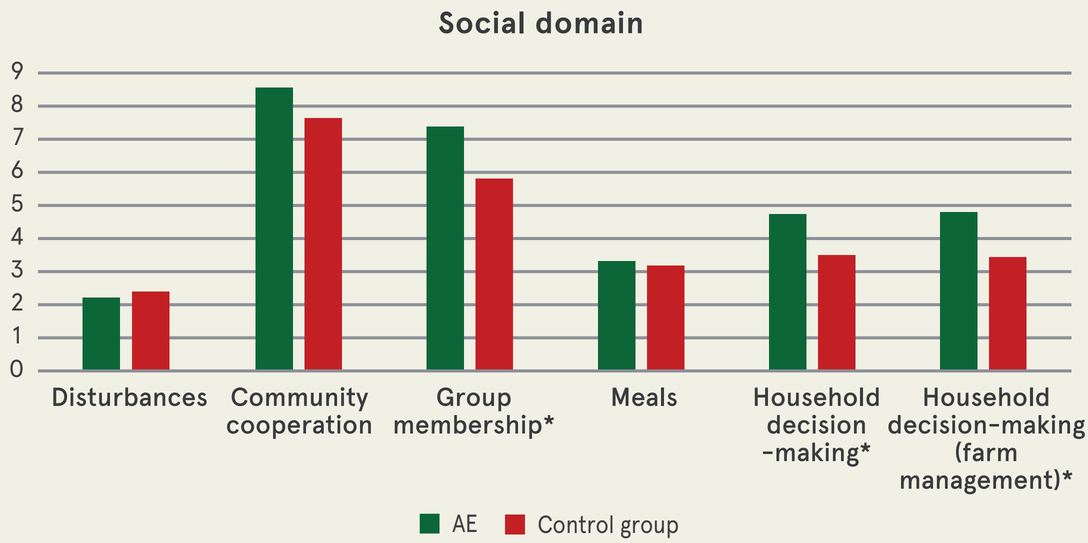
Based on the averages of the technical scores, there is a **significant difference between AE farms and the control group for the social domain** ($p<0.01$), which covers the modules concerning disturbances, community cooperation, group membership, meals, decision-making at household level and in farm management. It should be noted that even if there is no statistically significant difference, there is a distinct higher average score for AE farms in the agronomic field compared to farms in the control group (5.67 and 5.20 respectively).

Detailed results: per domain – Social

Agroecological farms were found to have a higher level of resilience in the social domain than the control group, with the statistical difference at $p<0.01$. **Figure 27** below shows which of the themes under this domain had significantly higher mean scores and table 12 further explains the implications of these themes on their contribution to resilience building within the agroecosystems, in particular agroecological systems.

FIGURE 27.

AVERAGE TECHNICAL SCORES FOR MODULES WITHIN THE SOCIAL DOMAIN



** Denotes statistical difference at (p<0.05).*

TABLE 10.

SELECTED SHARP THEMES FOR WHICH AGROECOLOGICAL FARMS WERE FOUND TO HAVE STATISTICAL DIFFERENT RESILIENCE SCORES IN THE SOCIAL DOMAIN COMPARED TO THE CONTROL GROUP, AND THE IMPLICATION OF THESE DIFFERENCES

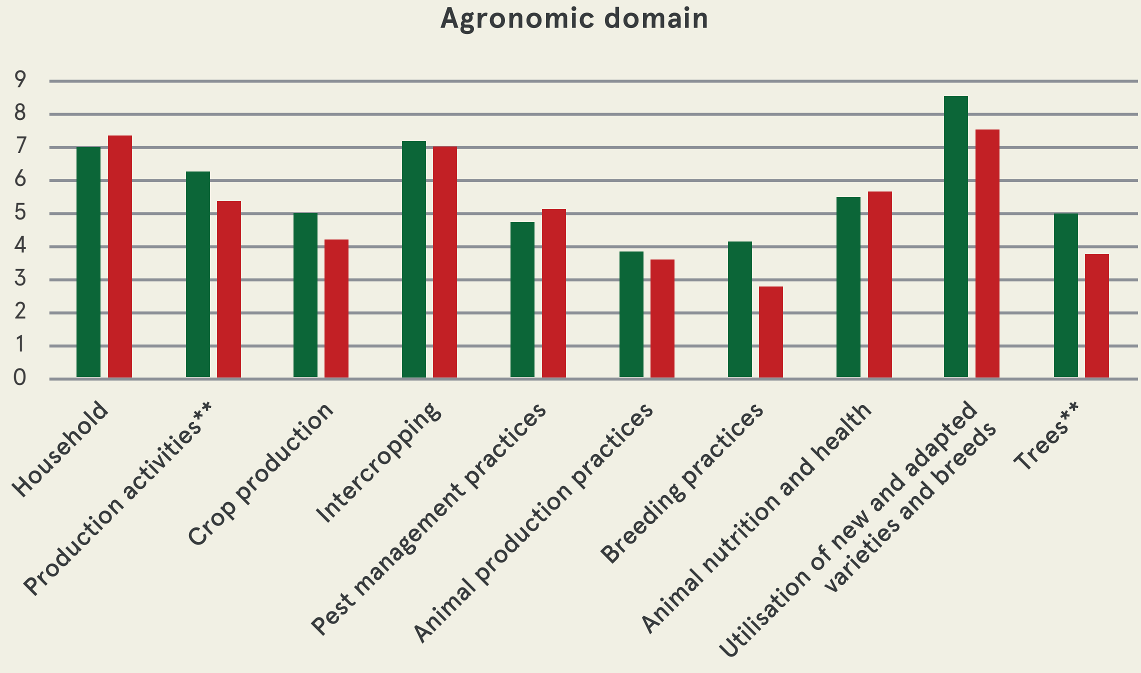
MODULES WITH A STATISTICAL DIFFERENCE	INTERPRETATION
GROUP MEMBERSHIP	The difference is significant at (p<0.05) for this sub-indicator, implying that agroecological farms are very well interconnected with their communities, promote knowledge exchanges on agricultural practices (crops, animals, forestry and fisheries) and traditional knowledge.
DECISION-MAKING (FARM MANAGEMENT)	The difference is significant at (p<0.05), implying that on agroecological farms, decisions about farm activities and farm management are probably taken in a more collaborative manner by household members (especially the head of household and his/her partner); whilst the load of activities are divided more equally among the household members. It is important to note that agroecological farms generally require more labour, which is often family sourced.
DECISION-MAKING (HOUSEHOLD)	The difference is significant at (p<0.05), indicating that on agroecological farms, household decisions are made jointly by the members of the household (especially the head of the household and his / her partner) and housework equally shared. This implies that the agroecological farms are able to benefit from the experience and knowledge of its members without relying on one member who may have limited knowledge or exposure with regard to some of the aspects of farm management.

Other domains

Figures 28 and **29** below illustrate the detail resilience scores with agroecological farms often showing higher resilience scores than the control group. This can be observed mainly under SHARP agronomic domain which had higher resilience mean scores for about five SHARP themes (trees, utilization of new and adapted varieties, breading practices and production activities). For the SHARP environment domain, agroecological farms had relatively higher mean scores for about two SHARP themes (use of leguminous plants and land management practices). In order to have a more robust result and have a better understanding of statistical differences, the analysis over time could be considered.

FIGURE 28.

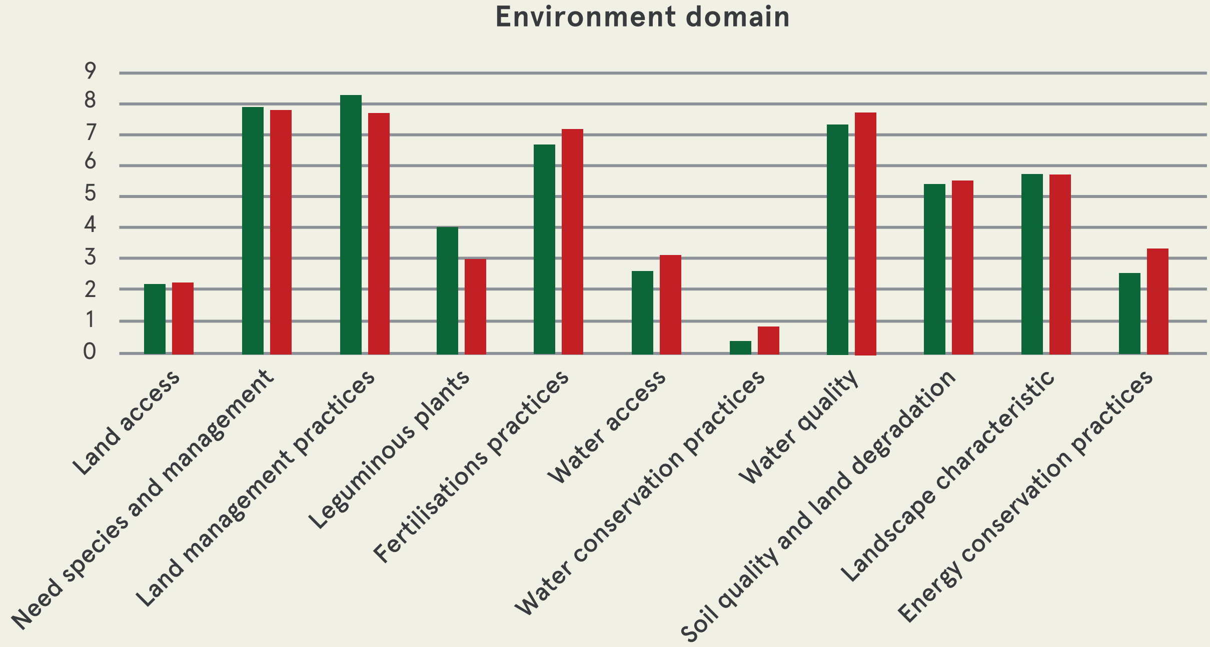
COMPARISON OF RESILIENCE LEVEL OF DIFFERENT SHARP THEMES UNDER THE SHARP AGRONOMIC MODULE FOR BOTH AGROECOLOGICAL FARM AND THE CONTROL GROUP



*NB: ** Denotes statistical significance at p<0.01.*

FIGURE 29.

COMPARISON OF RESILIENCE LEVEL OF DIFFERENT SHARP THEMES UNDER THE SHARP ENVIRONMENT MODULE FOR BOTH AGROECOLOGICAL FARM AND THE CONTROL GROUP

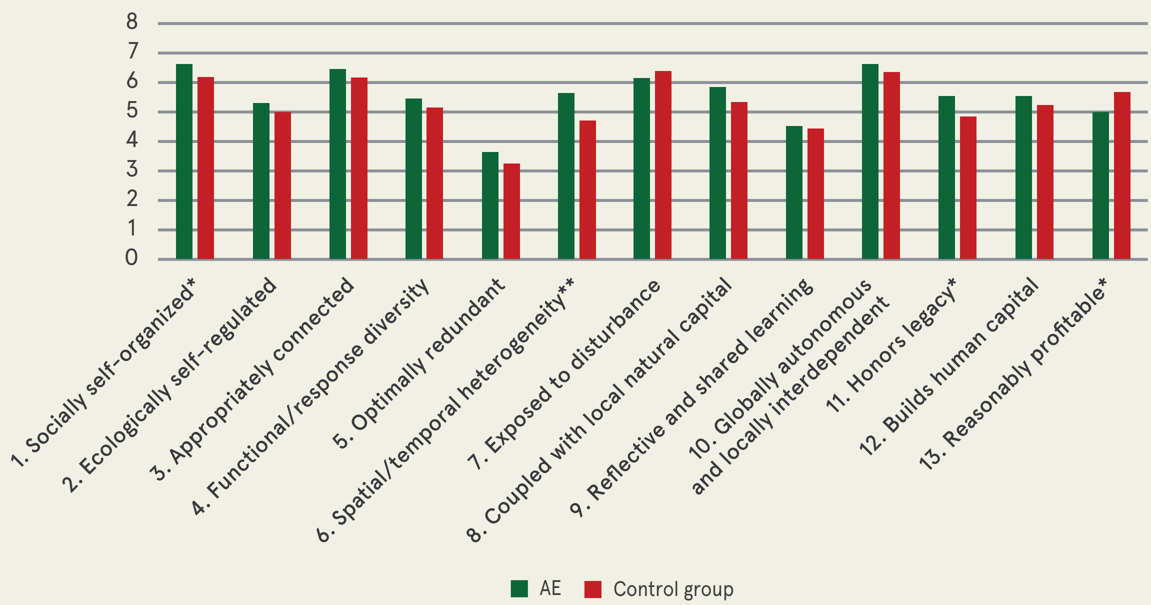


Detailed results for all farms: Agroecosystem resilience indicators

This section provides a detailed analysis of the results of the 13 agroecosystem resilience indicators between the agroecological farms and the control group (**Figure 30**).

FIGURE 30.

13 AGRO-ECOSYSTEM RESILIENCE INDICATORS BY TYPE OF FARM: AE AND CONTROL GROUP IN SENEGAL



*NB: * Means statistical difference at p<0.05 and ** at p<0.01.*

Socially self-organized indicator

The *socially self-organized* indicator assesses the ability of farmers to organize themselves into networks and basic institutions such as cooperatives, farmers' markets and community sustainability associations. According to Berkes (2007), self-organization constitutes the capacity to construct cross-scale connections and partnerships that allow systems to respond to change in new ways. There was a significant difference for this indicator between AE farms and the control group ($p<0.01$). The need to maintain ecological processes within the agroecosystems without yield penalty has enabled the agroecological farmers to build innovative institutional arrangements that maintain linkages of farms as units to the wider community. This self-organization nature of agroecological farmers is a crucial factor for their sustenance and thus their resilience to any type of shock including climatic. In a survey-based study aimed at identifying some of the factors strengthening the resilience of family farms in Austria, Darnhofer (2010) found that farmers perceive their ability to self-organize in different social fabrics to be a crucial factor for strengthening their resilience and that ability to cooperate and build networks is key for their future survival.

In this study, agroecological farmers were found to have different knowledge sharing mechanisms and belonging to different grassroots institutions such as cooperatives, organized farmers markets, all of which allow them to self-organize and thus to exhibit higher levels of resilience compared to the control group.

Ecologically self-regulated indicator

No significant differences were observed between the agroecological systems and the control group for this indicator. For agroecological farms, this indicator has a higher score than for the control group (5.4 versus 5.03). The indicator measures the performance of farms in maintaining land cover, their ability to provide habitat for predators and parasitoids, their ability to use ecosystem engineers and to align the production with local ecological parameters. The degree to which a system becomes capable to self-regulate is a function of interactions between different elements within the system (Barabas *et al.*, 2017). It was noted that AE farms cultivate a diversity of crops and practices which allows them to cover their land.

Appropriately connected indicator

This indicator implies connectedness not only from a social point of view, collaboration with several suppliers, points of sale and to other farmers; but also from an ecological point of view, the crops are planted in different mixtures that encourage symbiosis and mutualism. The difference was not significant but agroecological farms had higher resilience scores compared to the ones in the control group (6.5 versus 6.2). The lack of statistical differences between these two groups may be due to the fact that the connections between systems' components and within the system in agroecological farms had had not enough time for the interactions between the systems' components to effect change. Picasso *et al.* (2011) emphasised the importance of time for systems to assume a new state before benefits could accrue. They found that the biomass yield in the polyculture systems, with diverse species mixtures, became higher than that of the monoculture after three years, indicating the positive complementarity effects among different species, thus higher connectedness. From the social standpoint, Cabell and Oelofse (2012) state that, for farms to assume a higher resilience level, connections should not be with one network but rather with multiple networks. The performance of a system with regard to resilience is not based on one element's performance being dominant but rather performance based on multiple connections (Axelrod and Cohen, 1999). Therefore, for farmers to assume higher levels of resilience as effected by this indicator, they will need to expand their social networks and establish more ecological connections.

Functional/response diversity indicator

This indicator reflects the heterogeneity of functions within the landscape and farm; the diversity of inputs, outputs, sources of income, markets, pest control, etc. There was no significant difference in this indicator with regard to these two systems, but a higher average for AE farms was observed (5.4 versus 5.1). However, the difference was significant ($p<0.05$) for the sub-indicator "species diversity" which shows that on AE farms it is easier to observe crop diversification in terms of types (annual and perennial cultivars), species and varieties. Species diversity in agroecosystems is essential in spreading the risks during the time of shocks. Different species respond differently to different shocks.

Optimally redundant indicator

The indicator implies the level of functional redundancy within the farm; different elements of the farm serving the same purpose (duplication of a function). This serves as a buffer in case of shock occurrence. This indicator is measured by features related to the planting of several crop varieties rather than just one, keeping several animal breeds, obtaining nutrients from multiple sources and capturing water from multiple sources. There was no significant difference with regard to this indicator, but AE farms had higher average resilience scores (3.6 compared to 3.2 in the control group). However, there was significant differences observed in the sub-indicators that measure the diversity of cultivated varieties and animal production practices. Agroecological farms often embrace diversity (particularly biological) as it serves some of the critical ecosystems' functions.

Spatial/temporal heterogeneity indicator

This indicator measures heterogeneity within the agricultural system and landscape. It considers aspects related to the diversity of agricultural activities, resource management practices and as well as diversity within landscapes. Agroecological farms had a significantly higher degree of spatial and temporal heterogeneity ($p<0.05$) than the control group.

At the level of the sub-indicators, these differences are visible with regard to intercropping and crop mix ($p<0.01$), and also with regard to the presence of trees on the farm ($p<0.05$).

Spatial heterogeneity in agroecological systems is expressed mainly through intercropping and plant mixtures such as in agroforestry. The potential of intercropping as a resilience-building strategy can be in reducing pathogen pressure (reducing vulnerability) and in managing soil water dynamics in the occurrence of drought or even floods (Himanen *et al.*, 2016).

Heterogeneity in agroecosystems can also be temporal (Cabell and Oelofse, 2012) and these could be expressed through crop rotations especially cover cropping. The use of cover crop has potential as a resilience or adaptation strategy, in particular for soil water management. In Zimbabwe, Thierfelder *et al.* (2017) found that the use of cover crops resulted in soil water increase of over 45 percent when compared to bare fields during planting. This has implication in terms of germination rates and therefore ultimate crop yield.

Heterogeneity in both of these contexts could be seen as contributing to agroecosystems' resilience as does, diversity. However, these management strategies can be challenging to farmers as they require extensive knowledge of crop combinations and sequencing. The connectedness of agroecological farmers with a multiplicity of networks and knowledge sharing platforms may help with this challenge in the long run and therefore maintain their resilience levels.

Exposed to disturbance indicator

The indicator seeks to assess the level to which the farm system has been exposed to a discretionary level of disturbances and thus, evaluating its capacity to withstand and overcome them. Disturbances are captured by the exposure to climate and non-climate related shocks, while the behaviours towards them are captured by a number of management practices used (e.g. pest management practices, coping mechanisms).

There is a significant difference with increased scores for the control group with an average of 6.4 versus 6.1 for AE farms. The difference can be found in the sub-indicators measuring weed management and pest management practices.

Most respondents experienced climate-related shocks but only about half of them declared to have changed their behaviour in response to these. The results show a big need for action to respond to climate-related shocks.

Coupled with local natural capital indicator

This indicator assesses the system's ability to sustain healthy ecosystems and their functioning and thus encourage the system to live within its own means and without depleting the natural resources base. It is measured with some of the sustainable land and water management practices including energy conservation practices. There was no significant difference for this indicator, but the average resilience scores for AE farms remains higher than the control group (5.9 versus 5.4).

Though there was no statistical difference with regard to this indicator and even at sub-indicator level, the higher mean scores of resilience for agroecological farms implies somewhat the use of local natural resource base for the management of the farms. Over time, the continuous use of this natural capital could result in improved ecosystem functions which would be a crucial factor in enhancing the resilience of agroecological farms. In the spatial heterogeneity indicator, it was observed that agroecological farms employ more of the SLM practices. It may be that under coupled with natural capital indicator, there is still some level of dependence on the imported inputs for farm management and this becomes a diluting factor to some of the benefits derived from the use of natural capital.

Reflective and shared learning indicator

This indicator measures the collaboration between extension and advisory services for farmers, universities, research centres and farmers that allow the improvement of production practices and livelihood overall. It also indicates cooperation and knowledge sharing among farmers (for example, to improve bargaining power and market access, enhance productivity); record keeping; and basic knowledge of the state of the agroecosystem. There was no statistical difference on this indicator between the two groups. However, a significant difference was observed for the market access sub-indicator ($p<0.05$). AE farmers are most often members of marketing networks or sales cooperatives, in fact in Niayes, AE farmers are part of a participatory guarantee system that allows them to increase and keep a constant and profitable selling price of their products. The knowledge and experience gained through these learning and sharing platforms are of importance as they allow farmers to anticipate the future situations (as informed by the past) and allow them to plan in accordance through adaptation planning. This shows that agroecological farmers may not just be reactive to disturbances but anticipative as well – implying higher levels of adaptive capacity.

Globally autonomous and locally interdependent indicator

This indicator measures independence from the global level and solidarity and inclusion at the local level. It also assesses the level of inter-dependence of farms at the market level on the supply of raw materials and the reduction in the use of external inputs, sales on local markets, the use of local resources, the existence of farmers' cooperatives, close relations between producer and consumer, and shared resources such as equipment. Resilience under this indicator refers more to how the systems are closed or circular. This circularity is assumed to develop the buffer capacity for the system against external shocks. There was no significant difference for this indicator between the two groups. However, at the sub-indicators level, a statistical difference ($p<0.05$) was observed for access to local markets, reliance on local crop varieties and animal breeds with agroecological farms having higher resilience scores. The use of local crop varieties and animal breeds by agroecological farms is an essential element for resilience as these species are adapted to the local physical and biological stresses including drought, heat, cold and diseases and pests (FAO, 2017). Moreover, traditional (local) varieties and landraces are often genetically diverse compared to their hybrid counterparts and this diversity is also a contributory factor in resilience building of agroecological farms (Swiderska *et al.*, 2011, unpublished). According to Altieri & Merrick (1998), agroecosystems that are established far away from the centres of origin tend to have weaker genetic defence systems against pathogens and insects and that makes them be most vulnerable to epidemic attacks, a situation that is expected to increase in frequency and intensity due to climate change.

Honours legacy indicator

The legacy of traditions is a measure of the preservation and use of traditional and indigenous knowledge in the practices used for agricultural production and in the way the farm is managed. In addition to knowledge, legacies can be in the form of genetic resources (Cabell and Oelofse, 2012). The evaluation of this indicator is based on sub-indicators such as community engagement of elders, preservation of traditional knowledge, customary mechanisms, use of tree products, disease management and the use of combined traditional and new varieties.

Agroecological farmers scored significantly higher for this indicator ($p<0.1$). At the sub-indicator level, we observe that agroecological farmers have greater use of tree products as natural remedies as well as for crop protection ($p<0.05$). Also, significant differences ($p<0.05$) are found in the use of local and new varieties and breeds with agroecological farms having higher resilience scores.

In their development of innovative drought early warning systems in sub-Saharan Africa, which integrate indigenous knowledge with information technology, Masinde (2015) says the importance of indigenous knowledge in this context is to ensure the system's relevance, acceptability and resilience in the new environment. Thus, the use of indigenous knowledge in agroecological systems is among other factors that improve resilience in agroecological systems.

Builds human capital indicator

This indicator measures how well people are capable of managing shock and stresses as determined by the skills and knowledge they possess (Cabell and Oelofse, 2012). It is assessed by the following sub-indicators: household wellbeing, knowledge of land management, infrastructure access, active group participation, household decision making and investment in human capital. There was no statistical difference on this indicator between the agroecological farms and the control group even at the sub-indicator level. However, agroecological farms had higher resilience scores compared to the control group (5.6 compared to 5.2). Becker (1975) sees human capital as a stock of knowledge and skills that considers the contributions of humans directly in the production process. The lack of difference on this indicator between the two groups means that their skills and knowledge are at the same level when it comes to their contribution in agricultural production and the same with regard to resilience building. Though agroecological farms indicated higher participation in social networks and the knowledge of land management practices, this does not seem to positively influence their human capital.

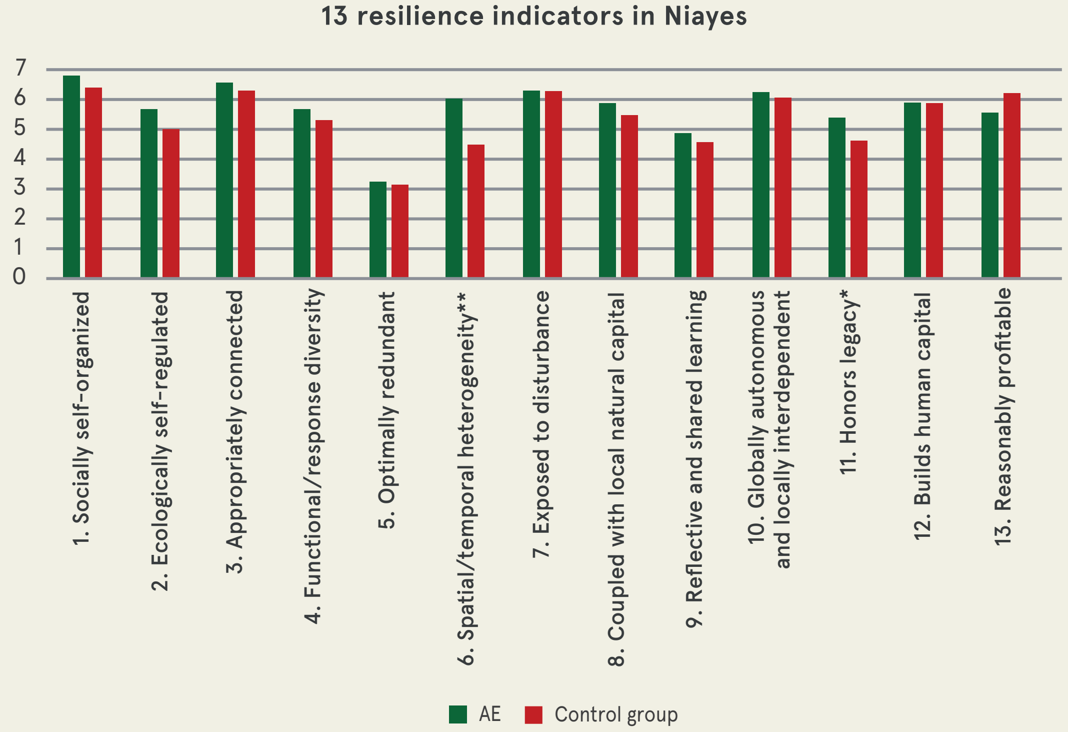
Reasonably profitable indicator

This indicator aims to assess the extent to which farmers and agricultural workers can earn a decent wage through agriculture and other non-agricultural activities. Profitability is assessed through the number of income sources of the agricultural holding, financial support received when needed, market access, productive assets held, insurance, savings and post-harvest handling practices to improve the produce value. For this indicator, the control group had a higher level of resilience than AE farms with a significant difference at ($p<0.1$). Also at the sub-indicator level, the control group had a significant difference for the insurance sub-indicator ($p<0.05$) indicating a higher ability to financially protect their products (e.g. crops, livestock, land) against loss or damage. This practice is more observed among the control group farmers who grow field crops in Koussanar, but is less so among vegetable producers in the Niayes. The ability of the control group farmers to insure their produce and assets shows that these farmers are producing profitably and highlights the importance of being able to protect assets against any loss or damage that may occur.

Context-specific findings: per agroecological zone - Niayes

FIGURE 31.

COMPARISON OF 13 RESILIENCE INDICATORS BETWEEN AGROECOLOGICAL FARMS (AE) AND THE CONTROL GROUP IN NIAYES



*NB: ** Shows significance difference at p<0.05 and * at p<0.1.*

Significant differences can be observed for indicators *spatial and temporal heterogeneity* (p<0.05), honours legacy (p<0.1) and ecologically self-regulated (p<0.1) in Niayes agroecological zone (**Figure 31**).

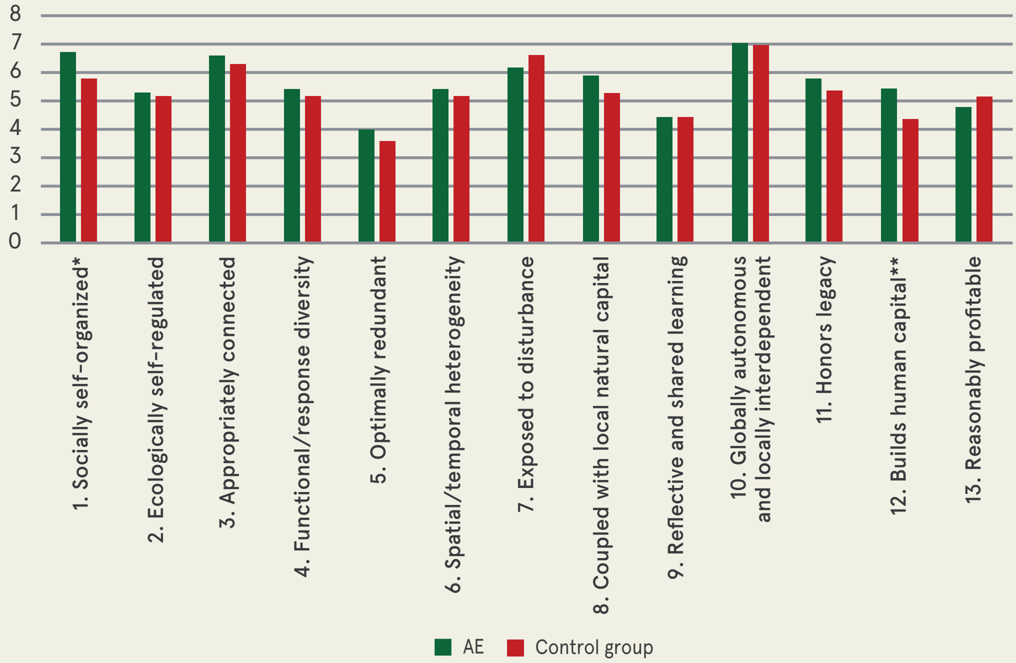
In AE farms, several plant species are grown on the same land, including seasonal and multi-annual crops and a wide variety of crop species grown and intercropping is more common on these farms. Agroecological farms use more natural/biological methods to manage animal diseases (biological pesticides, biological control methods, manual capture of pests found on crops, use of traps or trap plants, increasing biodiversity around fields to allow other pest control insects).

Challenged by the high use of pesticides and synthetic fertilizers in the Niayses area, Enda Pronat has undertaken the promotion of the "Healthy and Sustainable Agriculture" (*Agriculture Saine et Durable*), "characterized as an agriculture, which is: economically viable, ecologically sound, meeting food security requirements and underpinned by an organizational dynamic of producers in partnership with support and research structures" (Enda Pronat, 2012). Diversification both across space and time is what seems to be a contributing factor of resilience for agroecological farms. Diversity in this context is both in terms of biological diversity of crop species and the of different farm management practices. Another factor that is contributory to the resilience of agroecological farms is their use of traditional and indigenous knowledge. The application of this knowledge helps with context specificities and the relevance to the local realities. This systems memory, as exhibited by the honouring of legacies, also helps the agroecological farms to be more resilient than their conventional counterparts.

Koussanar

FIGURE 32.

COMPARISONS OF 13 RESILIENCE INDICATORS BETWEEN AGROECOLOGICAL (AE) FARMS AND THE CONTROL GROUP IN KOUSSANAR AGROECOLOGICAL ZONE



*NB: ** Denotes significance difference at p<0.05 and * at p<0.1.*

Significant differences can be observed for the socially *self-organized* indicators (p<0.1) and *builds human capital* (p<0.05) with agroecological farms having higher resilience scores (**Figure 32**).

Agroecological farms were found to be very well interconnected with their communities and this really facilitates support among farmers, and such is of importance in building both social and human capital. This is exhibited in the indicators *socially self-organized* and *building human capital*, both of which agroecological farms scored higher. Producers participate and integrate their basic institutions such as cooperatives, farmers' markets, community sustainable development associations, community gardens and advisory networks and are often also accompanied by NGOs' support.

OVERALL CONCLUSIONS: TECHNICAL POTENTIAL

The SHARP analysis of the full sample of farms indicates that overall AE farms have a higher level of resilience than the control group (with a mean resilience score of 5.2 versus 4.8 respectively).

Each indicator was assessed using sub-indicators, which are key entry points of possible interventions to strengthen resilience with internal and external measures. The comparison showed that out of the 13 indicators studied, agroecological farms have on average a higher level of resilience on 3 indicators, while control group had a higher resilience score on one indicator.

The three positively significant indicators that most contribute to a greater adaptability and resilience of agroecological farms are:

a. maintaining a high diversity within their farm system(spatial and temporal heterogeneity);
b. a better capacity to self-organize; and
c. preservation and use traditional knowledge and traditions within and outside the farm activities (*honours legacy*).

For point (a) above, significant positive differences were observed regarding **varietal diversity** (giving an indication of the number of breeds owned and the number of varieties grown), and **polyculture systems being highly developed among AE farms**. Agroecological farmers also make **greater and more frequent use of traditional varieties of crops and animals breeds adapted to local conditions**, especially in Koussanar, a livestock producing and agricultural area.

Self-organization (point b) shows that AE farms are well connected to their communities and share knowledge on sustainable development issues.

As a result of the transfer of traditional knowledge through their grassroots organizations, agroecological farmers are more likely to use trees as natural remedies, natural treatment products and as a means of soil fertilization (point c). Agroecological farmers also integrate tree products to a greater extent in agricultural production and as energy for domestic use (firewood).

Limitations and vulnerabilities of AE farmers include poor access to effective natural treatment products for pest control and weed management, as well as limited access to financial services and insurance. These results are highlighted by the significant difference regarding the reasonably profitable indicator (for which the control group had a higher score). Therefore, enhancing the access of producers to knowledge on how to manage pests in an integrated and sustainable manner is key to build their resilience levels. Likewise, improving their access to financial services like credits or insurance would also increase farmers' ability to invest in more and better productive assets, protect them against (expected and unexpected) shocks and increase their liquidity, among others.

Context-specific conclusions of the findings; per agro-ecological zones

By splitting the sample into the two agroecological zones contained, the following more disaggregated results are found (**Table 11**).

TABLE 11.

COMPARISON BETWEEN NIAYES AND KOUSSANAR, ON AGROECOSYSTEMS RESILIENCE THAT WERE STATISTICALLY SIGNIFICANT BETWEEN AE AND CONTROL GROUPS. FOR THESE INDICATORS, AE HAD HIGHER RESILIENCE SCORES

ZONES	SIGNIFICANTLY DIFFERENT AGROECOSYSTEM RESILIENCE INDICATORS		
Niayes	Spatial and temporal heterogeneity	Honours legacy	Ecologically self-regulated
Koussanar	Builds human capital	Socially self-organized	

In the Niayes area, out of all the indicators studied, AE farms show on average a higher resilience on 11 indicators, including 3 with a significant difference: "spatial and temporal heterogeneity" ($p<0.05$) and the "honours legacy" and "ecologically self-regulated" ($p<0.1$). The "temporal and spatial heterogeneity" indicator presents significant differences between AE and control farms, meaning that in the Niayes area, which is a favourable area for vegetable production, there is a diversity of crops, the practice of intercropping and crop rotation. Jointly, these practices not only improve the diversity of production, but also enhance soil health and serve as a mechanism to help prevent from pest invasion and plant diseases. Nonetheless, in this area, shortfalls for AE farms are noted on access to financial services. Therefore, the focus should be on access to financial services, in terms of finding financing mechanisms for AE farms to enable them to increase their investment options and thus, their agricultural potential.

For Koussanar, AE farms present higher resilience scores on 9 indicators, 2 of which have a significant difference: the "socially self-organized" ($p<0.1$) and the "builds human capital" ($p<0.01$). These results suggest that in this area, the manner in which farming systems and agricultural-reliant households work promote the strengthening of human capital that mobilizes social relationships and resources, improving households' well-being, economic activity, technology, infrastructure, individual skills and abilities, whilst facilitates social organization and norms. Being an area that is also practically cultivated during winter, the use of pesticides is less intensive and therefore the health of the population is less exposed.

The analysis of the results shows weaknesses in indicators related to disturbance, as well as pest and weed management. Therefore, it would be key to focus on strengthening producers' ability to manage weeds and pests in a sustainable, ecological and effective manner to enhance their resilience.

CHAPTER 5

CHAPTER

5

CONCLUSIONS AND RECOMMENDATIONS

5.1 OVERALL CONCLUSIONS

Summarizing the detailed and chapter-specific conclusions from the various components of this study on the international policy potential, the meta-analysis and the two case studies we can conclude:

5.1.1 Agroecology is gaining momentum on the international policy level

We systematically assessed the potential for agroecology (according to FAO's ten elements' definitions) to be considered and recommended as a relevant adaptation or mitigation approach in the international agriculture-climate discussions (UNFCCC and KJWA). The analysis revealed that:

- An increasing number of countries and stakeholders from different backgrounds see agroecology and related approaches as a promising means for reaching adaptation and mitigation targets and to achieve an effective transformational change.
- More than ten percent of the NDCs explicitly mention "agroecology", as either an adaptation strategy (11 percent) or as mitigation option (4 percent).
- Without addressing agroecology specifically, isolated agroecological approaches are also mentioned in NDCs, picking selected agroecological elements, such as "efficiency", "recycling", "diversity" and "co-creating of knowledge". The systemic nature of agroecology and especially its socio-economic and political elements receive far less attention. Submissions by observers to the UNFCCC, especially those of some CSOs, are much more demanding and call for a fundamental transformation of the food system. Moving forward, it would therefore be critical to look at agriculture through systems views which are inclusive of its social and human capital as these seem to contribute considerably to the agroecosystems resilience.

- Many countries recognize in their NDCs the need for institutional mainstreaming of climate change aspects in various sectors. Due to the holistic nature of agroecology that considers integration, connectedness, diversity, synergy and less dependence on external resources for food production it could be mainstreamed into agricultural and related sectoral plans. This could be done through the already existing policy frameworks, from which the majority of the NDC implementation activities are derived from. Embedding resilience into productivity and production could be carried out for example by integrating approaches like agroecology and agroforestry into sustainable land and water management policies (IPCC, 2019). For this integration to happen, it may be necessary to develop coordination mechanisms across different ministries which will develop and implement these integrated policies for the wide-spread and coherent adoption of agroecological approaches.

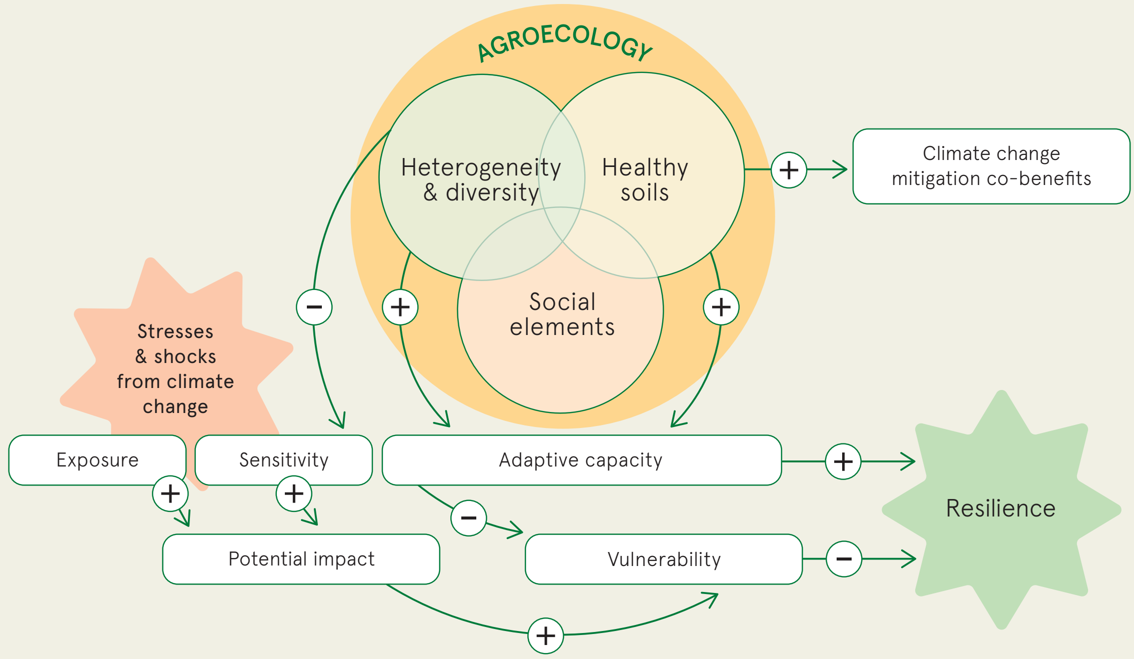
5.1.2 Solid scientific evidence demonstrating that agroecology increases climate resilience

The meta-analysis of peer-reviewed studies on agroecology (n=34 meta-analysis and 17 case studies selected out of 185) brings forward some clear patterns:

- Agroecology builds on key characteristics which have a strong positive correlation with climate resilience.
- Most solid evidence on strengthening climate resilience through increased adaptive capacity and reduced vulnerability is through improved soil health, high levels of agro-biodiversity and high diversification, for instance integrating different breeds, varieties and species into agricultural production systems and thus increasing productivity and maintaining yield stability (**Figure 33**).
- Mitigation co-benefits are also achieved, mainly related to increased soil organic matter (carbon sequestration) and reduced use of mineral nitrogen fertilizers.
- Institutional aspects, such as knowledge co-creation and dissemination through advisory services and farmer-to-farmer approaches have a key role to support the development, improvement and uptake of agroecology.
- When supporting agroecology and fostering climate resilience, it is key to establish and strengthen functional and context-specific knowledge and participatory innovation systems.

FIGURE 33.

SUMMARY OF MAIN AGROECOLOGICAL RESILIENCE STRENGTHENING PATHWAYS



5.1.3 Lessons learned from Kenya and Senegal

Policy potential

The national case studies assessed each country's institutional frameworks with regards to its potential to integrate agroecology in order to hedge against climate change. The analysis provides a deeper understanding of the current national context, the prevailing policy environment as well as the opportunities and challenges for agroecology to be considered in the decision-making process and to scale it up.

While Kenya and Senegal have different policy settings, in both countries there is considerable potential for agroecology to gain recognition. However, it is challenging to translate the interdisciplinary and systemic nature of agroecology into policies, laws and strategies. Both case studies highlight the importance of training and awareness-raising activities to ensure a common understanding of agroecology and to ensure it is embraced by appropriate institutional frameworks.

FINDINGS FROM THE KENYA POLICY ANALYSIS

- Climate-related policies in Kenya do not emphasize systemic, ecologic farming approaches but selectively address agroecology elements such as soil and water conservation practices.
- Through increased understanding of agroecology, stakeholders see opportunities for integrating it into sub-national institutional processes.
- There exist opportunities to embed agroecological approaches into existing policies.
- Further efforts to provide evidence, training and policy guidance for agroecology would need to be matched with increased levels of public and private investment and financial support. Government, in particular, can utilize its procurement power and regulation to influence the investment in agroecology. This can be through a provision of incentives for the adoption of agroecological products or subsidizing for the prices paid for.

FINDINGS FROM THE SENEGAL POLICY ANALYSIS

- Agroecology emerged in the 1980s in Senegal and many promising initiatives spread out since then that have influenced policies. However, policies and laws do not yet include agroecological approaches, as there is still a strong focus on high external input dependent agricultural systems.
- Favourable conditions for scaling-up agroecology exist today: 1) an increasing institutional commitment, since agroecological transition ambition is included in the government's priorities (among the five major initiatives of the *Plan Sénégal Émergent* 2019-2024); 2) the strong multi-stakeholder group DyTAES aspires to develop a contribution document to transform national policies and work towards an agroecological transition.

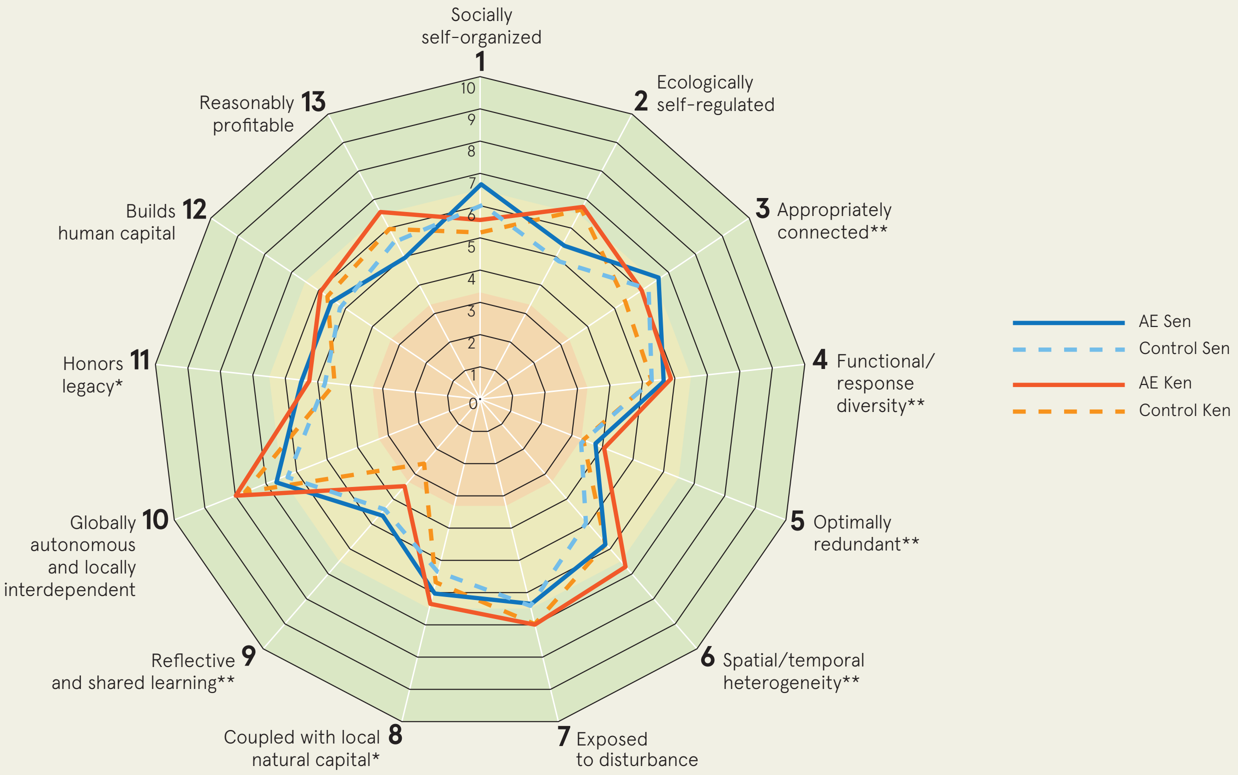
Technical potential

In both countries, a comparative analysis of 40-50 farmers that have been included in agroecological projects supported by Bioversity, Enda Pronat and ICE for more than five years versus 40-50 farmers non-participating in the agroecological programs (control group), was conducted to gain a better understanding of the ecological and socio-economic resilience performance of agroecology (based on the FAO SHARP tool):

- Overall results show that agroecological farmers have significantly higher SHARP resilience levels compared to the control group (non-agroecological farmers).
- These agroecological systems have a higher capacity to absorb, cope with, adapt to climate change and are therefore more resilient.
- In both countries and despite very different contexts, spatial and temporal heterogeneity as well as integrating and sharing of traditional knowledge ("honours legacy") (**Figure 34** and **Table 12**) were both significantly higher in the agroecology farms, which indicates that they are key aspects in strengthening resilience in agroecosystems, particularly agroecological systems.

FIGURE 34.

AVERAGE SHARP SCORES OF KENYA'S (KEN) AND SENEGAL'S (SEN) AGROECOLOGY AND CONTROL GROUP, BY RESILIENCE INDICATOR



The results of this study support the claim, that agroecology should be acknowledged as a powerful approach to transform agricultural production systems for a more sustainable and climate-resilient future. This corroborates what some Latin American countries have stated in their NDCs (**Chapter 2**), that agroecology should be considered as the base for the transition to more sustainable food systems.

TABLE 12.

LIST OF INDICATORS WHERE GREATER ADAPTABILITY AND RESILIENCE IS SHOWN BY AGROECOLOGICAL FARMERS IN KENYA AND SENEGAL

AGROECOLOGICAL FARMERS SHOW GREATER ADAPTABILITY AND RESILIENCE IN TERMS OF:	
KENYA	SENEGAL
3. Appropriately connected (i.e. access to information, forecasts, markets, participatory guarantee schemes)**	
9. Reflective and shared learning indicators (i.e. higer farmer group participation & access to extension)**	
11. Honours legacy indicator (i.e. higer integration of trees for natural remedies, pesticide and fertilization due to the transfer of traditional knowledge)*	**11.** Honours legacy indicator (i.e. use of local and new varieties and breeds that are adapted to local conditions; greater use of tree products as natural remedies)*
5. Redundancy (functional and species diversity i.e. numbers of crops)**	
5. Optimally redundant (i.e. variety diversity)**	
6. Spatial and temporal heterogeneity (i.e. intercropping; crop mix; terracing, wind breaks, presence of tree in the farm)**	**6.** Spatial and temporal heterogeneity (i.e. intercropping; crop mix; terracing, wind breaks, presence of tree in the farm)*
8. Coupled with local and natural capital (i.e. substitution of external inputs)*	
	1. Socially self-organized (i.e. ability of farmers to organize themselves into networks and basic institutions such as cooperatives, farmers' markets and community sustainability associations)*

Technical potential in Kenya

- For 7 out of 13 SHARP indicators, agroecology-based systems perform significantly better.
- The agroecology group scores better in the averages of environmental aspects, economic components and significantly better in agronomic practices.
- Both the agroecological systems and control group identified similar priorities and needs for further support, in particular insurance, animal breeding, non-farm income-generating activities, access to water and land.

Technical potential in Senegal

- For 3 out of 13 SHARP indicators, agroecology-based systems perform significantly better.
- The agroecology group performed significantly better on social-related indicators, and better for agricultural practices. Same performance levels as the control group were reached for the economic and environmental related aspects.
- Barriers for agroecological farmers include access to effective biological products for pest control and weed management, as well as limited access to financial services and insurance.

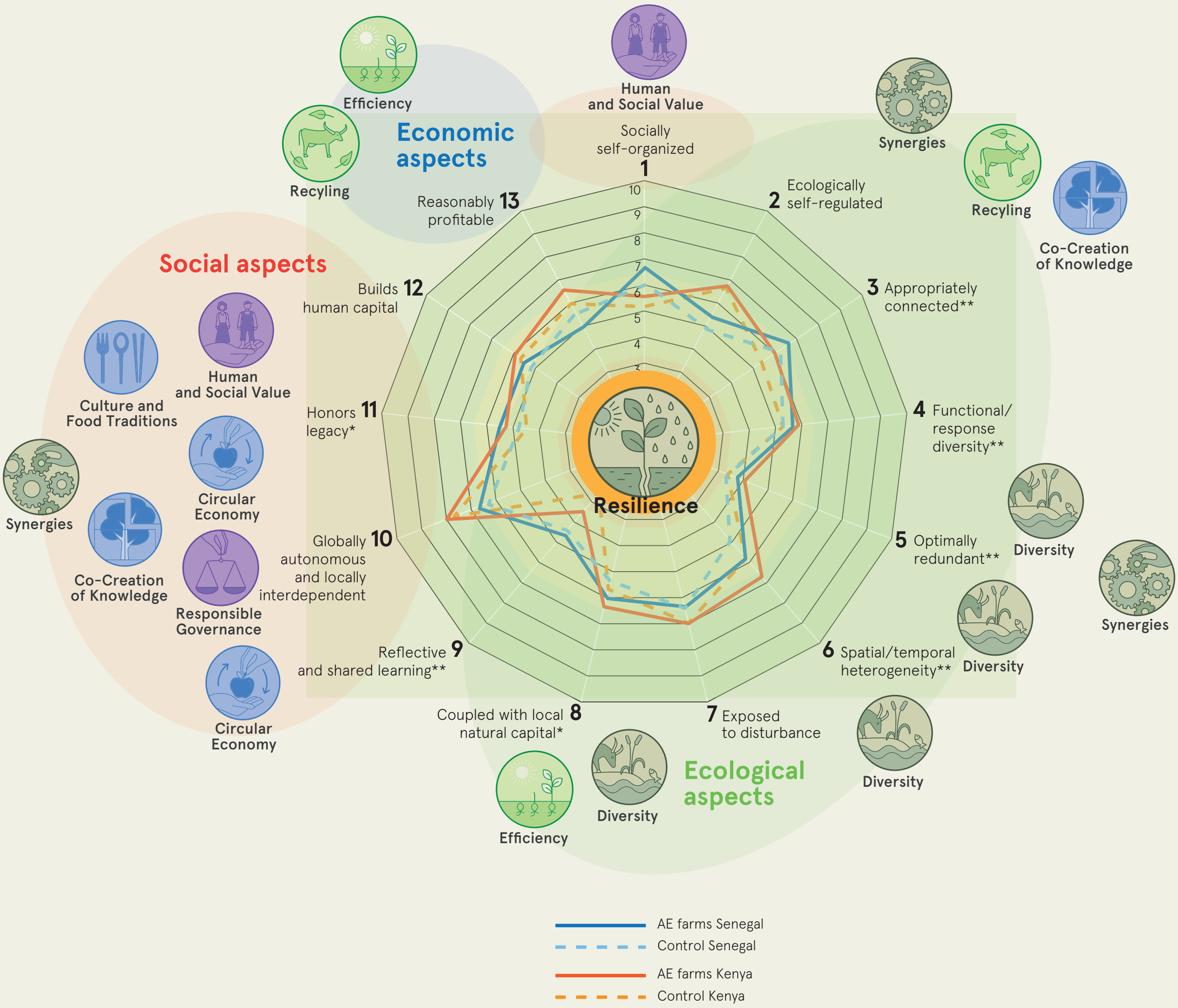
GENERAL OBSERVATIONS ON AGROECOLOGY FROM A RESILIENCE PERSPECTIVE

The following graph summarizes the findings of this study in a simplified way, depicting the interactions and the close connectedness of the agroecosystems resilience concept (represented by the 13 indicators from Cabell and Oelofse, 2012) and the characteristics of agroecology (as described by FAO's ten elements) (**Figure 35**). The core principles on which agroecology builds (i.e.: diversity, efficient use of natural resources, nutrient recycling natural regulation and synergies) characterizes its inherent adaptation and resilience potential to climate change (Côte *et al.*, 2019). This interconnection between the two concepts is the exact reason why agroecology, from a conceptual point of view, possesses an inherent resilience potential to climate change. In the below figure, the resilience potential (and one of the 10 elements of FAO) is therefore represented at the heart of the radar, with the idea that it embraces it all.

In this study, we have gathered evidence from various perspectives that allow us to conclude that agroecology indeed strenghtens the resilience of smallholder farms and contributes to their adaptation to climate change. For instance, the findings revealed the importance of the social and human capital. The ability of agroecological farmers to self-organize and engage in common learning and information sharing allows them to form broader social safety-networks that buffers them against disturbances, both climatic and economic. Building on traditional knowledge and wider management skills passed down through generations also contributes to increased resilience. Diversification through agroecology builds the natural capital of the farms. Higher levels of biological diversity and heterogeneity in these farms improves biogeochemical processes like nutrient and water cycling, increases stability as well as improves soil organic matter that adds to soil fertility and overall soil health. These processes are fundamental for resilience building and adaptation to climate change. Lastly, diversification of different aspects of food systems is a crucial element that manifests into increased resilience, reduced risks and maintained stability of food production in the wake of shocks and stresses.

FIGURE 35.

HOW CAN AGROECOLOGY (DEPICTED BY THE 10 FAO AGROECOLOGY ELEMENTS, IN CIRCLES) STRENGTHEN RESILIENCE? THE GRAPH ILLUSTRATES HOW CLOSELY CONNECTED AND INTERTWINED THE PROPERTIES OF RESILIENCE, MEASURED BY THE 13 INDICATORS OF AGROECOSYSTEMS RESILIENCE ACCORDING TO CABELL AND OELOFSE (2012), ARE WITH THE 10 ELEMENTS OF AGROECOLOGY



5.2 RECOMMENDATIONS

According to the HLPE (2019) and numerous other high-level reports (IPCC 2019, Sachs *et al.*, 2019), a profound holistic and systemic transformation is needed to address climate change as well as achieve the Agenda 2030, and the four dimensions of FSN: availability, access, utilization and stability. It is also necessary to face further multidimensional and complex challenges, including a growing world population increasing pressure on natural resources, impacting land, water and biodiversity.

5.2.1 Overall key recommendations

- Given the sound knowledge base, fostering agroecology to build resilience should be recognized as a viable climate change adaptation strategy.
- Barriers to the scaling-up of agroecology need to be addressed: amongst others, improved access to knowledge and understanding of systemic agriculture approaches should be fostered across sectors, stakeholders and scales.

- Further comparative research on the multidimensional impacts of agroecology is needed.
- Agroecology's transformative resilience-building potential depends on its holistic and systemic nature which goes beyond a set of practices and includes: a social movement for producers' empowerment and a multidisciplinary scientific paradigm.
- Science and policy interfaces are necessary. The Koronivia Joint Work on Agriculture (KJWA) should be continued to ensure this interface, turning the submissions and recommendations into action.

5.2.2 Further recommendations to donors, decision-makers and other stakeholders

To address the multidimensional challenges and fostering climate resilience in food and agriculture, donors, decision-makers and other stakeholders should:

- Embrace complexity, adopt a more systemic understanding of challenges and solutions to hedge against climate change, grasp environmental issues in a holistic way and move towards more policy coherence, by breaking silos and working across not only agricultural sectors, but others as well such as natural resources and energy.
- Acknowledge that the current knowledge base is robust enough to support agroecology as an effective climate change adaptation strategy and strengthening farmers' resilience.
- Increase investment in research on agroecological approaches, support transdisciplinary and participatory action research, conducted by innovation platforms and centres of excellence that foster co-creation of knowledge and dissemination and serve as the learning hub for agroecology.
- Provide capacity development and training to the agricultural advisory services on the dynamics of agroecology and to promote awareness about agroecology to farmers.
- Develop comprehensive performance metrics, covering all the impacts of agriculture and food systems, for rational decision-making and efficient resource allocation at all levels
- There are no "one-size fits all" solutions, no silver bullets: consider individual contexts and local knowledge, building on the ten elements of agroecology.
- Integrate agroecology into different sectoral plans, strategies or policies. Policies and strategies that support agroecology should build on existing policies and strategies as much as possible, instead of creating new ones. Thereby, perverse incentives and other hindering policies, such as input support for intensive production should be abandoned. Furthermore, strategies and policies advocating for the use of agroecological practices should take multisectoral, multistakeholder and national and sub-national unsustainable approaches to ensure its success.

5.2.3 Recommendations in the context of Koronivia

- Seize the opportunity of the workshop on socio-economics related aspects and consider associated submissions to move agroecology forward.
- Build on the core aspects of agricultural resilience demonstrated in this study: diversification, biodiversity, healthy soils and enhanced social and human capital within agroecological systems.
- Science and policy interfaces are necessary for agriculture and food systems in the UNFCCC and other related international frameworks. Mechanisms should be put in place to allow for the closer interaction between the negotiators and the scientific community during the UNFCCC processes (SBI, SBSTA and COPs). Currently, science-based activities such as side-events receive less attention and support from the negotiators who are key to the process as are decision-makers.
- NDC momentum: seize the 2020 NDC year of revision to further incorporate agroecological approaches as a way forward towards transformational change.
- Raise awareness on the contribution of agroecology on enhancing the resilience of food systems as a means of advancing KJWA and putting more emphasis on the non-production elements of agroecology as they build human and social capital of agroecosystems.

5.2.4 Recommendations to researchers and donors

- Further Long-term studies are needed that allow the identification and assessment of the performance of farm systems in general, and agroecological in particular. This will generate evidence to support agroecology as a means to transitioning to more sustainable and resilient food systems. For this to be realized, the donor community will need to fund longer-term studies or projects that will provide necessary evidence on the performance of agroecological systems.
- There is a need for greater integration of scientific and traditional knowledge to enhance participatory action research and for both of the knowledge systems to benefit from each other.
- Projects and programmes should ensure adequate capacity development of the beneficiaries as this builds a human capital that is critical for building resilience. Sufficient funding should be allocated for such activities within projects.

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ANNEXES

ANNEX 1.
List of stakeholders interviewed (for sections 2.3 and 2.4)

INVOLVED/NOT INVOLVED IN KJWA	CATEGORY OF INTERVIEWEE		NAME
Involved	**Government (4)**	Senegal Negotiator	Mr. Lamine Diatta
Involved		French Negotiator	Mrs Valerie Dermaux
Involved		Kenya Negotiator	Ms Veronica Ndetu
Involved		Swiss Negotiator	Ms Christine Zundel
Involved	**UN organization (2)**	Climate Change, Natural Resources Officer	Mr Martial Bernoux
Involved		Climate Change, Natural Resources Officer	Mrs Julia Wolf
Not directly involved		CCAFS	Mr Dhanush Dinesh
Involved	**Research (5)**	INRA	Mr Jean-Francois Soussana
Not directly involved		INRA	Ms Claire Weill
Not involved		INRA	Ms Allison Loconto
Involved		IDDRI	Mr Sébastien Treyer
Not involved	**CSOs and environmental organizations (3)**	IPES-Food	Mr Emile A. Frison
Involved		Secours Catholique	Mrs. Sarah Lickel
Not involved		Le Gret	Mr Laurent Levard
Involved	**Farmers organizations (1)**	United Kingdom National Farmers Union	Ms Ceris Jones

ANNEX 2.
Literature review

2.1 Meta-analysis and reviews

We searched for meta-analyses on (1) the performance (with respect of a number of agronomic, environmental or social indicators) of agricultural practices or production systems that are part of or closely related to agroecological production systems, such as organic agriculture or agroforestry; (2) the relation between a number of sustainability indicators to the characteristics of agricultural production systems or ecosystems in general that closely relate with characteristics of agroecological production systems and with climate change adaptation; an example is the relationship between diversity and productivity. We identified the meta-analyses by web-searches in Google Scholar and discussion with experts.

Search terms were “meta analysis”, “meta review” and “review” combined with search terms for production systems: “agroecology”, “agroforestry”, “organic agriculture”, “organic farming”, “permaculture”, “reduced tillage”, or for system characteristics (“diversity”), and with search terms for indicators related to climate change impacts and adaptation (“productivity”, “yield”, “performance”, “income”, “stability”, “resilience”, “extreme events”, “drought”, “pests”, “diseases”) – and variations of these terms. These search terms cover key aspects of climate change adaptation and resilience as framed in (FAO, 2015).

While compiling this literature database, we also added related literature which we occasionally identified while scrolling through the studies, e.g. from the reference list, or which have been pointed out to us by other researchers directly.

This search resulted in 51 review articles, whereof 33 were statistical meta-analyses, and 18 more descriptive literature reviews.

Part of the single system comparison studies identified above is also covered in these meta-analyses and reviews. This is, however, no problem, as the search for and analysis of the single system comparison studies aimed at identifying and synthesizing the evidence on "agroecology" (and some closely related systems) and "climate change adaptation", while the meta-analyses are designed to address single specific aspects and characteristics of these two topics only.

2.2 Compilation of the results from the meta-analysis, the values show changes in comparison to the baseline

Columns contain indicators addressed; rows contain systems, practices, characteristics analysed.
Values: percent change with respect to baseline; some studies report different sub-indicators with different values, where we then summarize the results into qualitative values and trends, these are reported by "+" and "-"; values from different studies in the same cell are separated by semicolon ";".
Bold print: significantly different; normal print: not significant.
Green: better preformance than the baseline; (Light green: not significant).
Yellow: worse preformance than the baseline; (Light yellow: not significant).
Grey: no effect.
Red: practices reported in meta-analyses that may not deemed agroecological in all cases.
Blue: indicators referring to temporal stability/variability.

INDICATORS										
SOIL HEALTH										
Systems, practices, characteristics	Soil, organic carbon contents	Soil organic carbon sequestration rates	Stability of SOC and C sequestration	Total soil N	Soil aggregate stability	Soil dry room density	Infiltration	Soil loss	Surface runoff	Soil fertility/Various beneficial phisical soil properties
Organic agriculture	**+**[6]	+[6]	0[33]		15[23]	-4[23]	**137**[23]	-22[23]	-26[23]	
Low-input systems								**-**[24]		
Agroforestry (incl. silvopastoral)										**+**[24]
No tillage	**5**[1]									**+**[12]
Reduced tillage	**5**[1]; **+**[34]			**+**[34]		**+**[34]				**+**[12]; **+**[34]
Cover crops	**5**[1]; **8**[30]			**13**[30]						
Biochar	**35**[1]									
Organic fertilizer (incl. residues left on fields)	**+**[34]			**+**[34]						**+**[12]
Crop rotations/ crop diversity/ intercropping	**+**[30]	**+**[32]		**+**[30]						
Grassland diversity										
Biodiversity general										

INDICATORS (CONTINUED)												
SOIL BIODIVERSITY												
Systems, practices, characteristics	Soil microbial activity	Soil microbial biomass	Soil microbial functional diversity	Soil biodiversity/ microbial diversity/ richness	Soil bacterial diversity	Soil micro, meso and macro diversity	Abundance of soil microbial communities	Arbuscolar mycorrhizal fungi diversity	Nematode abundance	Nematode community diversity/ stability	Food web indices	Earthworm abundance and biomass
Organic agriculture	**50**[14]	**45**[14]		2[4]			**60**[14]					**85**[23]
Low-input systems			0[4]		5[4]	-5[4]		15[4]	**+**[13]			
Agroforestry (incl. silvopastoral)	**+**[20]											
No tillage												
Reduced tillage	**+**[34]	**+**[34]								**+**[29]	**+**[29]	
Cover crops		**+**[30]										
Biochar												
Organic fertilizer (incl. residues left on fields)			10[4]		**7**[4]	10[4]			**+**[13]	0[29]	0[29]	
Crop rotations/ crop diversity/ intercropping		**25**[30]		**3**[25]; **15**[25]								
Grassland diversity												
Biodiversity general												

INDICATORS (CONTINUED)								
GENERAL BIODIVERSITY					PLANT PROTECTION			
Systems, practices, characteristics	Species richness	Species abundance/ diversity	Arthropod diversity/ richness	Stability of species richness/ abundance	Natural plant protection	Level of biological control	Animal pest abundance	Weed abundance
Organic agriculture	**+**[22]; **30**[27]	**+**[27]	**+**[28]	**+**[33]		+[15]	-[15]	**+**[15]
Low-input systems	**9**[2]; **+**[13]							
Agroforestry (incl. silvopastoral)	**50**[20]; **+**[24]	**50**[20]						
No tillage								
Reduced tillage								
Cover crops								
Biochar								
Organic fertilizer (incl. residues left on fields)	+[13]							
Crop rotations/crop diversity/ intercropping	**15**[25]				**+**[11]			
Grassland diversity								
Biodiversity general								

INDICATORS (CONTINUED)												
	PRODUCTIVITY										EMPLOYMENT	HEALTH
Systems, practices, characteristics	Pathogen abundance	Total biomass production	Stability in total production	Yield		Yield stability	Resource use efficiency	Ecosystem services stability	Profitability	Stability of costs and profits	Rural employment	Exposure to pesticides
Organic agriculture	-[15]			**-20**[21]		**-15**[9]	0[23]		+[26]	0[33]	+[22]	-[22]
Low-input systems				**-20**[2]								
Agroforestry (incl. silvopastoral)		+[20]										
No tillage				**-7**[16]		-3[9]						
Reduced tillage		-[34]		+[34]								
Cover crops												
Biochar												
Organic fertilizer (incl. residues left on fields)		-[34]		+[16]	-[34]							
Crop rotations/ crop diversity/ intercropping			+[19]	+[10]; -[11]; +[16]	**2.2**[18]; **10**[31]	+[17]; +[18]						
Grassland diversity				**50**[8]								
Biodiversity general				+[3]; +[5]			+[3]	+[3]				

References with notes

Blue references: indicate studies on general ecosystems (or grasslands without grazing/mowing: Isbell *et al.*), not focusing on agricultural production services.

Code references		Notes
1	Bai *et al.* 2019	Values displayed are averaged over a number of more differentiated analyses, e.g. for soil type, climatic zone, duration of the experiment, etc.
2	Beckmann *et al.* 2019	Addresses effects of intensification, we framed it the other way round to capture the agroecologicla aspect of extensification; differentiates results between intensity levels: at low intensities, intensity increases did not affect species richness and yields; at high intensities, it increased yields but did not affect species richness, at intermediate levels, positive impacts on yields and negative on species richness were largest.
3	Cardinale *et al.* 2012	Refers to ecosystems and not to agricultural production systems.
4	De Graaff *et al.* 2019	Refers to increase of soil bacterial and fungal diversity with N fertilization. Applications of less than 150kgN/ha lead to an increase in bacterial diversity, of more than 150kgN/ha lead to an insignificant decrease; mineral N does not lead to an increase, while organic N does. N fertilization leads to a decrease in arbuscular mycorrhizal fungi diversity of about 10%, but applications of less than 150kgN/ha lead to an insignificant reduction of 5% only, while applications higher than 150kgN/ha lead to a significant decrease of 20%.
5	Duffy *et al.* 2015	Refers to ecosystems and not to agricultural production systems.
6	Gattinger *et al.* 2012	Reports absolute changes with respect to the baseline, not relative to the baseline values; reports data from net zero input systems only, as only those reflect the nutrient recycling paradigm of agroecology.
7	Garcia-Palacios *et al.* 2018	Now additional data added - for their meta-analyses, they use largely the same data as Gattinger *et al.* 2012 (with some additional data, without changing anything significantly).
8	Isbell *et al.* 2015	Refers to grasslands without cattle, etc. and thus not to agricultural production systems in a more narrower sense; the 50% increase in stability are derived from the following numbers: productivity losses in ecosystems due to climate extremes are 50% in systems with few species, while they are only 25% with many species.
9	Knapp and Van der Hejden 2018	
10	Lesk *et al.* 2015	We report a weak signal only, derived from their statement that the lower yield impacts of extreme events in developing countries may be due to the more diverse production systems.
11	Letourneau *et al.* 2011	Q23 is significant (difficult to display above); Natural plant protection covers reduced pest abundance and damages and increased natural enemy numbers; crop-diversification covers various intercropping schemes and more detailed results are displayed in the paper.

12	Li *et al.* 2019	Reports on a number of physical soil properties such as bulk density, water stable aggregate, soil available water capacity, etc. – we display them all together with the significantly positive signal reported only. "Organic fertilizers" mean here the retention of crop residues in no- and reduced-tillage systems.
13	Liu *et al.* 2016	The entry on species richness is not significant; Species refer to nematodes, results are differentiated according to different types of nematodes and organic fertilizers, C-rich (straw, etc.) are more beneficial to nematodes than slurry, etc.; species richness generally decreaes with N fertilization, with the exception of organic N fertilizers, while nematode numbers increase with all fertilization, but the most with organic ones; from this we also derived the positive signal for low-input systems that come with less N.
14	Lori *et al.* 2018	Soil microbial biomass is the average of microbial N and C increases; abundance of soil microbial communities and soil microbial activity are derived from various proxies reported in the paper (activity is based on 4 values at 74%, 84%, -4% (not significant) and 32% - we grossly capture this in 50%).
15	Muneret *et al.* 2018	Crowder *et al.* 2010 shows similar results but assumingly covers partly the same and less data, hence we did not cover it.
16	Pittelkow *et al.* 2015	Looks at conservation agriculture, which is no-till, residue retention and crop rotation; in general, no-till leads to lower yields, while the other two aspects lead to increases again. The yield responses are different for different contexts, and under dry conditions, full conservation agriculture with all these three elements leads to significantly higher yields by about 7%.
17	Raseduzzaman and Jensen 2017	Here, crop diversity is intercropping.
18	Reiss and Drinkwater 2018	Crop diversity is crop mixtures; overall, the yield is 2.2% higher with mixtures; only considering misxtures with 4 or more components, the yield increase is 4%; differences also occur between crops, where the yield increase is around 8% for corn and around 4% for legumes. The design of the mixture is also relevant for the yields (intention and basis), and the mixtures perform also better in the face of stressors, in particular under high disease pressure; finally, differences occur between climate zones, mixtures in the tropics showing yields that are by 10% higher, in temperate zones 2% only.
19	Renard and Tilman 2019	The study refers to crop diversity and stability of total production at national levels.
20	Santos *et al.* 2019	Agroforestry significantly correlates with higher ecosystem services provision - those are measured with a number of specific variables, here, we report on Microbial activity and total production, but others such as litter decomposition, etc. are also covered; performance for biodiversity was between 45% and 65% higher, so we report 55%; for ES, the signals are more heterogeneus, so we report the sign and significance only.
21	Seufert 2018	Many further details on determinants of yield gaps, some discussion of yield stability, etc., referring a number f other meta-analyses on the topic.
22	Seufert and Ramankutty 2017	A study covering a number of other meta-analyses. We report the results from those not yet reported and that link to CC adaptation and resilience.
23	Sanders and Hess 2019	A German study synthesising a large number of other meta-studies on the performance of organic agriculture in temperate zones along a number of indicators; earthworm abundance and biomass combine the signals for those of 78% and 94%.
24	Torralba *et al.* 2016	Agroforestry in Europe.
25	Venter *et al.* 2016	Soil microbial richness +15%, soil microbial diversity +3%.
26	Crowder and Reganold 2015	Also covered in Seufert and Ramankutty 2017, but reported separately.
27	Tuck *et al.* 2014	Expands the meta-analysis of Bengtsson *et al.* 2005; effects are largest in intensively managed landscapes.
28	Lichtenberg *et al.* 2017	
29	Bongiorno *et al.* 2019	Inconclusive effects of organic matter additions on nematode community diversity, etc.
30	McDaniel *et al.* 2014	Soil nicrobial biomass C and N was measured, increasing by 20% and 25%, respectively; almost in all cases, cover crops were legumes.
31	Ponisio *et al.* 2015	General effects on yields are captured in Seufert 2018; the effects reported on rotations refer to organic systems, i.e. the yield is 10% larger than in general organic systems (which have a yield gap of 20%) – hence the yellow colouring.
32	Poeplau and Don 2015	
33	Smith e*et al.* 2019	Based on meta-analyses already included, but adding a specific analysis of the variability of the indicators of interest.
34	Lee *et al.* 2019	Covers many practices and indicators; we report on those with sample sizes of 8 or more studies only.

2.3 Single system comparison studies

We did a literature review searching for peer-reviewed studies that compare agroecological production systems with some baseline and provide qualitative or quantitative evidence for the difference in performance regarding climate change adaptation ("single system comparison studies"). Thereby, we considered studies only that termed themselves to be assessing agroecology or agroecological practices. We thus neglect studies whose authors did not explicitly frame them in the context of agroecology. Given the inclusion criteria we used for them, these other case studies without explicit reference to agroecology are however to a large part already covered in the meta-analyses and reviews we searched for as described in the previous sub-section.

For the single system comparison studies, we used the following search terms in two search engines, completed in April 2019:

a) Web of Science:
- TOPIC: "climate change" AND TOPIC: "agroecology", scrolling through all results;

b) Google Scholar:
- "agroecolog*" AND "climate change", scrolling through the first 200 results.

As this search only captures articles that are self-declared to somehow refer to agroecology by the authors, we expanded the search to terms closely related to agroecology as follows:

- "permaculture" AND "climate change", scrolling through the first 100 results;
- "regenerative agriculture" AND "climate change", scrolling through the first 100 results;
- "silvopast*" AND "climate change", scrolling through the first 100 results; and
- "Zero budget natural farming" AND "climate change", scrolling through the first 100 results.

We complemented this search with a search for Spanish, French, Italian and Portuguese literature in June 2019 using the following search terms in Google Scholar, scrolling the first 100 results (in many cases much less were found):

- "agroecolog*" AND "cambio climatico"
- "permacultura" AND "cambio climatico"
- "agricultura regenerativa" AND "cambio climatico"
- "CSA" AND "cambio climatico"
- "agroecolog*" AND "changement climatique"
- "permaculture" AND "changement climatique"
- "agriculture regeneratrice" AND "changement climatique"
- "CSA" AND "changement climatique"
- "agroecolog*" AND "cambiamento climatico"
- "permacultura" AND "cambiamento climatico"
- "agricoltura regenerativa" AND "cambiamento climatico"
- "CSA" AND "cambiamento climatico".

For the literature in Portuguese, we approached Dayana Andrade, a PhD student in agroecology in Brazil; this did however not result in any additional studies.

While compiling this literature database, we also added related literature which we occasionally identified while scrolling through the studies, e.g. from the reference list, or which have been pointed out to us by other researchers directly.

This primary search resulted in 185 studies (120 E; 35 F; 23 ES; 4 I; 3P).

We then screened all studies for:

- being peer-reviewed or "close to it" (such as PhD theses);
- addressing climate change adaptation or related aspects (and not purely focusing on mitigation);
- whether they indeed analyse agroecology. This was determined by identifying whether practices from the framework from Biovision were analysed or not (cf. above). Only those articles referring to such practices have been retained for further analysis;

- whether they compare an “agroecological” to a “conventional” baseline situation. Studies reporting on agroecological situations without reference to a baseline with which to compare the performance to have been excluded from further analysis;
- whether they report quantitative or qualitative indicators for the differences in performance. Articles without such data have been excluded from the analysis.

This left us with 17 studies. Many studies had to be dropped because of lack of evidence, lack of a baseline for comparison, or because they represented reports from NGOs, research institutes, etc. without being peer-reviewed. In particular, the latter provide interesting information, but adopting a conservative approach, we could not include them in the analysis. Some of them are listed under the header “Examples of anecdotic evidence” in the database file: “Review_AgroecAndCCAdapt_LiteratureAnalysed.docx”.
For all these studies, we then reported:

- the agroecological practices implemented;
- the performance indicators used;
- the country, region, continent, where the study is located;
- the agroecological zone, in which the study is located;
- the scale of implementation of the practices (1 local; 2 regional; 3 national; 4 international);
- the FAO element the agroecological case refers to;
- the Gliessman level the agroecological practices refer to;
- whether the practices also show climate change mitigation potential or not (only qualitative evidence needed, coded as a binary indicator: 1 yes; 0 no);
- whether the study referred to a specific extreme event such as a storm or drought where adaptation or resilience become very well visible and can be observed on the ground in short time periods; and
- whether the study adopted a holistic approach attempting to covering agroecology in its whole complexity in its empirical approach.

2.4 Potential bias in the data

Besides the case studies that are self-declared agroecological, the data basis we compile also covers the huge number of case studies that analyse how agricultural production systems, practices and characteristics that strongly relate to agroecology (but without referring explicitly to this term) correlate with indicators of climate change adaptation and resilience. Examples are comparisons of organic versus conventional production systems with respect to yield stability, comparisons of different levels of species richness in agro-ecosystems with respect to total biomass production, or comparisons of systems with organic fertilizers to such with mineral fertilizers with respect to soil fertility. As these second type of case studies have repeatedly been synthesized in a number of meta-analyses and reviews on various topics, we do not search for these case studies specifically, but directly draw on the results from the corresponding meta-analyses and reviews. By this, we cover the knowledge based on case studies that do not explicitly refer to agroecology as well.

This approach may result in two types of bias, though. First, the review on the single case studies does not cover any study that is not self-declared agroecological. The studies without reference to agroecology are however covered in the meta-analyses and reviews included, and this bias in the choice of the case studies does thus not result in a bias in the knowledge base covered. Second, the meta-analyses and reviews may cover some of the single agroecological casestudies as well. However, given the low number of the latter compared to the huge number of studies covered in these meta-analyses and reviews, this potential double-count will neither result in any relevant bias.

2.5 Reviews on extension services and knowledge transfer

We use reviews on the role of extension, rural advisory services (RAS) and knowledge dissemination on the performance of agricultural production systems as a third body of literature for the assessment of the potential of agroecology for climate change adaptation. This is based on the assumption that to promote the transformation of farming systems through agroecology, effective innovation delivery is essential and that co-creation and sharing of knowledge is considered an integral part of agroecology (FAO, 2018). Furthermore, the mandate of RAS has widened from a productivity focus to a more holistic perspective, including, among other things, nutrition, livelihoods, gender and environmental sustainability issues, thus relating it closely to central aspects of agroecology (David and Cofini, 2017).

We used a large meta-study on agricultural innovation by the International Initiative on Impact Evaluation (3ie) as a starting point (Lopez-Avila, Husain *et al.*, 2017) and from there identified 3 articles of relevance, i.e. quantitative reviews on the effects of knowledge dissemination and co-creation on the performance of agricultural production systems. These do not directly relate to agroecology, but given the central role knowledge transfer and exchange plays in agroecology, they serve to potentially identify important patterns relating to this aspect of agroecology, just as we identified patterns relating to diversity from the meta-analyses above as one characteristic of agroecology, without specifically referring to papers explicitly addressing agroecology.

2.6 Data analysis

Due to the small number of studies identified and the heterogeneity of contexts and indicators reported, it has not been possible to perform a formal meta-analysis. We analysed the data as follows:

- Descriptive analysis of the Gliessman level to which the practices implemented in the single system comparison studies refer to.
- Descriptive analysis of the ten elements of agroecology to which the practices implemented in the single system comparison studies refer to.
- Descriptive analysis of the agroecological practices the single system comparison studies refer to.
- Descriptive synthesis of the performance of agroecology in the single system comparison studies regarding the FAO performance indicators, with a focus on the indicators most directly relating to climate change adaptation (9 agricultural biodiversity; 10 soil health), but also considering those more broadly relating to resilience (2 productivity; 3 income).
- Descriptive synthesis of the patterns identified in the complementary meta-analyses.
- Descriptive synthesis of the reviews on rural advisory services and knowledge transfer.

2.7 Data base

All data is contained in the excel-file "LiteratureReview_Data_1_11_2019.xlsx", the first Sheet "Notes" contains some information on its structure and contents.

All papers covered in the analysis of the single system comparison studies and the meta-analyses/reviews are referenced in the Word-File "Review_AgroecAndCCAdapt_Literature Analysed.docx".

ANNEX 3.
List of the literature analysed in the meta-analysis (chapter 3)

3.1 Single System comparison studies (#17)

*indicates studies (#5) with a holistic approach, presenting a comparably rather complete coverage and assessment of agroecology.
+indicates studies (#3) that build on a before/after comparison of an extreme weather event.

Balehegn, M., L. Eik and Y. Tesfay. 2015. Silvopastoral system based on Ficus thonningii: an adaptation to climate change in northern Ethiopia. African Journal of Range & Forage Science, 32(2).

Barkaoui, K., M. Birouste, P. Bristiel, C. Roumet & F. Volaire. 2015. La diversité fonctionnelle racinaire peut-elle favoriser la résilience des mélanges de graminées méditerranéennes sous sécheresses sévères?

*Bezner Kerr, R., J. Kangmennaang, L. Dakishoni, H. Nyantakyi-Frimpong, E. Lupafya, L. Shumba, R. Msachi, G.O. Boateng, S.S. Snapp, A. Chitaya, E. Maona, T. Gondwe, P. Nkhonjera & I. Luginaah 2019. Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. Agriculture, Ecosystems & Environment, 279: 109-121.

*Björklund, J., H. Araya, S. Edwards, A. Goncalves, K. Höök, J. Lundberg & C. Medina. 2012. Ecosystem-Based Agriculture Combining Production and Conservation-A Viable Way to Feed the World in the Long Term?

Bunch, R. 2000. More productivity with fewer external inputs: central american case studies of agroecological development and their broader implications.

*Calderón, C.I., Jerónimo, C., Praun, A., Reyna, J., Santos Castillo, I.D., León, R., Hogan, R. & Córdova, J.P. 2018. Agroecology-based farming provides grounds for more resilient livelihoods among smallholders in Western Guatemala. Agroecology and Sustainable Food Systems, 42: 1128-1169.

Diacono, M., A. Fiore, R. Farina, S. Canali, C. Di Bene, E. Testani & F. Montemurro. 2016. Combined agro-ecological strategies for adaptation of organic horticultural systems to climate change in Mediterranean environment. Italian Journal of Agronomy, 11: 85.

Garrity, D.P., F.K. Akinnifesi, O.C. Ajayi, S.G. Weldesemayat, J.G. Mowo, A. Kalinganire, M. Larwanou & J. Bayala. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Security, 2(3): 197-214.

+Holt-Giménez, E. 2002. Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring. Ecosystems and Environment.

*Kangmennaang, J., R.B. 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.

Martin, G. & M. Willaume. 2016. A diachronic study of greenhouse gas emissions of French dairy farms according to adaptation pathways. Agriculture, Ecosystems & Environment, 221: 50-59.

Montagnini, F., M. Ibrahim and E.M. Restrepo. 2013. Silvopastoral systems and climate change mitigation in Latin America. Bois et forets des tropiques, 316(2).

*+Rosset, M.P., B. Machín Sosa, A. María Roque Jaime and D. Rocío Ávila Lozano, 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.

Salazar, A. H. 2013. Propuesta metodologica de medicion de la resiliencia agroecologica en sistemans socio-ecologicos: un estudio de caso en los andes colombianos. Agroecologia, 8(1).

Souza, H.N.d., R.G.M. de Goede, L. Brussaard, I.M. Cardoso, E.M.G. Duarte, R.B.A. Fernandes, L.C. Gomes and M.M. Pulleman. 2012. Protective shade, tree diversity and soil properties in coffee agroforestry systems in the Atlantic Rainforest biome. Agriculture, Ecosystems & Environment, 146(1): 179-196.

+Speakman, D. & D. Speakman 2018. Growing at the Margins: Adaptation to Severe Weather in the Marginal Lands of the British Isles. Weather, Climate, and Society, 10: 121-136.

3.2 Examples of anecdotic evidence (#8)

For illustration, we provide some examples for the anecdotic evidence (of which there are many more), as these contain interesting and inspiring cases, but they cannot be included in a rigorous scientific synthesis:

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Cardona, C., J. Ramirez, A. Morales, E. Restrepo, J. Orozco, J. Vera, F. Sanchez, M. Estrada, B. Sanchez & R. Rosales. 2014. Contribution of intensive silvopastoral systems to animal performance and to adaptation and mitigation of climate change. Revista Colombiana de Ciencias Pecuarias, 27.

Gyasi, E. & K.G. Awere. 2018. Adaptation to Climate Change: Lessons from Farmer Responses to Environmental Changes in Ghana. Strategies for Building Resilience against Climate and Ecosystem Changes in Sub-Saharan Africa. O. Saito, G. Kranjac-Berisavljevic, K. Takeuchi and E. Gyasi, Springer.

Montalba, R., F. Fonseca, M. Garcia, L. Vieli & M.A. Altieri. 2015. Determinación de los niveles de riesgo socioecológico ante sequías en sistemas agrícolas campesinos de La Araucanía chilena. Influencia de la diversidad cultural y la agrobiodiversidad. Papers, 100(4).

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Oakland Institute, Biointense Agriculture training programm in Kenya.

Oakland Institute, Restoring ecological balance and bolstering social and economic development in Niger.

3.3 Meta-analysis (#34)

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3.4 Reviews (#19)

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3.5 Reviews on extension services and knowledge transfer (#3)

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ANNEX 4. Social dimension case study: perception of farmer communities

List of climate change-related questions for the FGD:

- In what year did they perceive that the climate has changed significantly? List extreme weather events that have occurred between the date identified and the present. Where there any changes in the start date of the rains or the length of the rainy season?

  Climate change has changed drastically from 2015 starting with El Nino rains of 2015/16 and the prolonged drought that has persisted from 2018 to date. Rainfall levels are below normal and cannot sustain rainfed agriculture. The just-concluded 'long' rains started late April and ended late may lead to crop failure especially for green grams, the most popular crop in Tharaka. No harvest for 2 years in some parts.
- Can you locate and mention the effects of this event on the map? How did this effect occur? For example: how were the crops lost? What crops have been lost? Due to increased heat? Due to a pest?

What pest? Is it new? Was there a lack of water in the flowering months?
The available maps do not capture 2016-2018. However, crop failure is mainly due to below normal rainfall around flowering time. Green grams, cowpeas and pigeon peas crop lost to the drought. Few cases of fall armyworm affecting maize (very recent).

- Please describe how this event affected soil, water, vegetation and/or crops and animals and/or livestock:
  Drought generally led to land/soil degradation, drying of crops and some streams and reduction in pasture plus other herbaceous plants leading to death of some livestock.
- If an area has been heavily affected, has this affected other areas to which it is connected? If so, how?
  When the higher grounds are degraded, the agropastoralists take their animals for grazing along riverines which results in riverine degradation due to overgrazing. In addition, erosion on uplands leads to pollution of rivers.
- Are areas that benefit more from nature more adapted to major climatic events? Have they been more or less affected by the changes? Has this affected the provision of services?
  Every part has been affected by climatic shocks but the protected areas like riverines and forests have retained some level of resilience amidst severe climatic changes.
- Why do they think that is? How do the species present in this area contribute to this observation?
  Forests and riverine are retaining a good level of moisture, and so plants growing there are more resilient. Soils in these areas are also not very vulnerable to erosion due to good protective vegetation cover.

Water:

- What changes have been observed in the water (decrease in sources, quality, etc.)? Where and since when? Why is this happening? How do they recognise them?
  Reduction in water volume due to aridification and over-abstraction; and sedimentation due to erosion (quality). Fifteen years little irrigation but now-> excess water with pesticides. People getting sick not very prominent. Some cholera.
- Do they know any method that is used to conserve the water system? (practices, plant/animal species). How do they do it?
  Yes. Tree planting and avoiding grazing in forests and riverines.
- What structure or species help to conserve water?
  Fig trees and herbaceous plants.

Seasonal calendar:

- What are traditional climate predictors, i.e. signals that allow them to predict the start of the given season? For example, the flowering of a specific tree that signals the beginning of the rainy season.
  Some changes in cosmos eg. stars (constellation studying by the elders); environmental changes like flowering of certain trees, shedding of leaves; birds movement (moving away from droughts and pest); insects like butterflies (move in a certain direction a lot of pests). Movements of the clouds southeast direction.
- What are the major diseases that affect the community and economic spending – over the seasons?
  Mostly pests like fall armyworm which destroy maize crop. New castle poultry disease during dry season. Flue with dry and cold and windy. Cholera with rainy season and floods.
  Most expenditure in dry season because of malaria and flues. Warm temperatures are good for breeding insect carrying diseases.

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