Chapter 1

An Introduction to the Climate-Smart Agriculture Papers

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1.1 Tracking Progress

In 2001, the Third Assessment Report of the Intergovernmental Panel on Climate Change highlighted the potential impacts of a changing climate on global agriculture. The Report stated that rising temperatures and drought could lead to significant declines in yields for many of the world's poorest nations, including Africa. This stimulated a new set of global commitments to research and promote agricultural practices that are more climate-smart. Since then, almost USD 1 billion has been committed to climate-smart programming in Africa, with more likely to follow (Fig. 1.1). Most African governments have formed climate-smart agriculture task forces. New transnational partnerships, such as the East African Regional Climate-Smart Agriculture Alliance, have linked government efforts to support regional change. In 2015, these commitments were reinforced by the adoption of a Statement

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Fig. 1.1 Investments and alliances promoting CSA in Africa. (Source: Authors)

of Shared Ambition for climate-smart agriculture and a subsequent Action Plan by the corporate members of the World Business Council for Sustainable Development (WBCSD 2015). What's more, non-governmental and some civil society organisations have formed complementary advocacy groups, such as the Alliance for Climate-Smart Agriculture in Africa (ACSAA) that includes international non-governmental organizations, policy institutions, technical partners and farmers groups.

The responses to these large commitments of strategic and financial support have been substantial. Hundreds of technological solutions have already been identified as climate-smart because they mitigate the effects of rising temperatures and variable rainfall; or contribute to a reduction of greenhouse gas (GHG) emissions; or accumulate carbon in biomass or soils (Table 1.1). New varieties of crops with greater drought tolerance are already in production, and more are being released each year (Challinor et al. 2016). Many land management systems conserve soil moisture (Thierfelder et al. 2017). Agroforestry systems reduce the ambient temperature of nearby crops and livestock (Lin 2007; Barton et al. 2016). Feeding strategies that increase productivity and reduce GHG emissions from livestock are well known (Bryan et al. 2013; Thornton and Herrero 2010). And information delivery systems help farmers to plan the right period(s) to plant.

Indeed, 'climate-smart' has bordered on becoming a brand. Carried to the extreme, today there are now climate-smart extension systems, climate-smart finance, climate-smart landscapes, climate-smart livestock, climate-smart soils, and climate-smart varieties etc. (Gledhill et al. 2012; Graefe et al. 2016; Minang et al. 2014; Paustian et al. 2016; Sala et al. 2016).

Whereas many technologies are available to help farmers better cope with climate risks, improving farmers' access to these technologies, while strengthening incentives around their adoption, remains the more significant challenge. Despite millions of dollars of investment, adoption rates of new agricultural technologies in much of eastern and southern Africa remain low (Giller et al. 2009; Asfaw et al. 2016). The majority of farmers continue to struggle with the costs and risks of new technologies. Increasing climate risks simply make these efforts more difficult.

This volume highlights current efforts being made by scientists in eastern and southern Africa in developing and disseminating climate-smart agriculture (CSA) technologies. Emphasis was placed on getting previously unpublished data written up and presented. Unlike many edited volumes, the book started with an open call for chapters on five key topics. More than 70 applications were submitted and evaluated against the criteria, which included: relevance of the topic, whether new data were being presented, and the quality of the science. Twenty-three applications were selected to move on to full chapter development. Twelve specific contributions were then commissioned by the book's editors to fill gaps in the discussion. After at least two technical reviews and multiple rounds of revision, 25 of these papers were accepted for publication within this volume. Unpublished chapters, which still contain important content for development, can be found on the webpage that accompanies this book.

Table 1.1 Different climate hazards and associated field- and farm-level adaptation interventions, by broad agricultural land use

Land use	Intervention	Climate hazard			
		Temp	Water	Variability	Flooding
C M	Improved crop varieties: dual-purpose, higher-yielding, stress tolerance (heat, drought, salinity, pests)	√	√	√	√
C M	Change crops: new mixes of crops of different characteristics (heat-, drought-tolerance), crop rotations	√	√	√	√
C M	Crop residue management: no till/minimum tillage, cover cropping, mulching		√	√	
C M	Crop management: modified planting date/densities, multicropping with legumes, agroforestry species	√	√	√	√
C M	Nutrient management: composting, appropriate fertiliser and manure use, precision nutrient application		√	√	
C P M	Soil management: crop rotations, fallowing (green manures), conservation tillage, legume intercropping		√		
C P M	Improved water use efficiency and water management: supplemental or reduced irrigation, water harvesting, modifying the cropping calendar, flood water control		√	√	√
P M	Change livestock breed: switch to more productive/smaller/more heat- and drought-resilient breeds	√	√	√	
P M	Change livestock species: switch to more cash-fungible species, use more drought- and heat-tolerant species	√	√	√	
P M	Improved livestock feeding: diet supplementation, improved pasture species, low-cost fodder conservation technologies, precision feeding			√	
C M	On-farm pond aquaculture as a low-emissions adaptation and livelihood diversification strategy	√	√	√	
P M	Improved animal health: disease surveillance, vaccination, disease treatment			√	
P M	Grazing management: adjusting stocking densities to feed availability, rotational grazing, livestock movement		√	√	
P M	Pasture management: use of sown pastures, setting up of fodder banks and other strategic dry-season feed resources		√	√	
P M	Manure management: anaerobic digesters for biogas and fertiliser, composting, improved manure handling, storage and application techniques			√	

(continued)

Table 1.1 (continued)

Land use	Intervention	Climate hazard			
		Temp	Water	Variability	Flooding
M	Alter system integration: alter animal species and breeds, alter the ratio of crops to pasture, or crops to livestock and/or to fish		✓	✓	
C P M	Use of weather information: seasonal forecasts for agricultural planning, and short-term forecasts for early warning of extremes such as high temperatures and heavy rainfall		✓	✓	✓
C P M	Index insurance for crops and livestock		✓	✓	✓

C cropland, P pastureland, M cropland and pastureland

Source: CCAFS and GCF (2018)

1.2 Overview of the Chapters

The 25 chapters in this book have been divided among 5 themes. Four chapters explore issues around climate change, including impacts and risks. Six investigate mechanisms in seed and crop germplasm delivery systems. Six examine various perspectives and lessons learned on technologies and practices through a CSA lens. Five more examine the resilience to climate change of value chains; and four look at financing, extension and other mechanisms to reach scale. Each chapter reflects on a fundamental question: how to make complex crop and livestock systems more climate-smart? Each chapter ends with messages on the implications for development practitioners to inform future decision-making.

The chapters that explore climate change, along with its impacts and risks, include one on future projections, two on impacts and one on systems. Girvetz et al. investigate the certainty and uncertainty of future climate change in sub-Saharan Africa. This involves longer term and near-term predictions of traditional indices, such as temperature and precipitation, as well as new bioclimatic indicators that help make forecasts relevant to the risks faced by agricultural systems. The authors use a freely accessible online tool known as Climate Wizard (www.climatewizard.org), which is available to practitioners to help them incorporate climate information in programme and policy design. Bett et al. describe two cases of how predicted climate change will affect the occurrence of livestock pests and diseases that already cause significant damage to livelihoods and economies. The authors' concrete recommendations around mitigating future impacts support the notion of taking action today to prepare for the challenges of tomorrow. Hunter and Crespo analyse the climate risks and impacts for both staple (maize and cassava) and cash (coffee) crops at the subnational level in Angola. The authors' findings demonstrate a clear need for future investments—for example, in long-lived coffee—despite the inherent uncertainty in climate models. Lastly, Masikati et al. look at the likely responses of maize and groundnut under climate change using common crop models. Their findings suggest that improved soil management can help mitigate future negative

risks to productivity. Taken together, these chapters illustrate why this type of research is critical in moving beyond projections of the future to concrete action that can be taken today. Nonetheless, commissioning this section of the book was not unproblematic, pointing to an urgent need for more information around climate change impacts and risks—detail that is instrumental for initiating meaningful conversations on CSA.

The next set of chapters describe the challenges and opportunities around improving the delivery of quality crop germplasm to farmers. Improved planting materials are typically among the first suggested responses to climate variability—whether today's or tomorrow's—and this section explores some of the limits of this conventional wisdom. Das et al. open with a private-sector perspective on seed systems. The authors describe bottlenecks in the delivery of cereal seeds along with the necessary changes—such as public–private partnerships—they feel are needed to make investment opportunities more conducive to the private sector. Ertiro et al. bring fresh evidence in support of the development of drought-tolerant maize in Ethiopia. Droughts are already an every-year occurrence in the country under climate change, and this case highlights a suite of actions needed to move from breeding to widespread use of new varieties. Cramer focuses on one specific link in the seed system chain—early generation seeds. By comparing a successful case with an unsuccessful one, the author identifies a few key stumbling blocks that extend the time taken in breeding, delivery and adoption. Parker et al. illustrate that many of the issues presented for cereal crops are also applicable to roots, tubers and banana—staples for 300 million people in the humid tropics of sub-Saharan Africa (SSA). However, the solutions recommended by the authors differ markedly to those of previous chapters due to the structure and development of the system that delivers vegetable planting-materials. Many of the challenges discussed—e.g. the lack of development and long generation time—are also presented in Dawson et al. In this chapter, authors discuss the contributions of trees and orphan crops to resilient food systems and make recommendations for investments that develop this system in future. Faddha and van Etten close this section by presenting a cost-effective participatory approach to evaluate varieties under farm conditions using novel material from national gene banks or plant breeding. Using a case study, the authors argue that this triadic comparisons of technologies (tricot) approach has the potential to contribute to making seed systems more dynamic when demand and supply are linked and more diversified, as more varieties per crop will be delivered in a location-specific way. Together, the chapters in this section of the book present a sobering picture of the current germplasm delivery systems; with a low penetration of improved varieties within agricultural systems (20%), even for most well-developed breeding programmes, and a long development time (13–30 years). This may signal a massive development opportunity for the seed sector within CSA.

Subsequent chapters present perspectives on the climate-smartness of various technologies and management practices. In particular, they unpack the evidence and lessons learned on what makes a technology climate-smart. Rosenstock et al. conduct a systematic map—a rigorous and structured analysis of the available data—to examine the impact of 73 technologies on indicators of productivity, resilience and

mitigation. They identify a significant skew in the available peer-reviewed literature towards maize-based systems, productivity outcomes and on-farm trials. This suggests that anyone interested in creating evidence-based programmes and plans will find many gaps in the scientific knowledge. A complementary quantitative approach towards assessing the multidimensionality of agricultural technologies can be found in Kimaro et al. Here, the authors collect agronomic data on the performance of technologies across the three pillars of CSA (productivity, resilience and mitigation) in three agroforestry systems of Tanzania (shelterbelt, intercropping and border plantings of fuelwood and food crops). Their findings highlight the perspective and flexibility needed to understand whether a technology is climate-smart or not. Performance assessments, however, only provide part of the evidence. Manda et al. design and pilot a participatory framework to evaluate practices against farmer-selected criteria of productivity and resilience. This qualitative approach can help fill gaps in knowledge—which other chapters of the book have pointed towards—while being farmer-centric. Mwungu et al. present an analysis of barriers to the adoption of a technology. Specifically, the authors investigate drivers behind the adoption of improved varieties in rural, post-conflict Uganda. They find that household size and information networks influence adoption, with results pointing towards both general and context-specific rules on the adoption of CSA technologies. For example, while household size is typically positively correlated with adoption, trust in information networks may be increasingly important in some contexts, such as post-conflict zones. Davies et al. analyse how culture and spirituality can affect the adoption of technologies. The introduction of culture as a determinant of adoption is unique in most discussions of technologies in general and of CSA in particular. This concern may be acutely pertinent for technologies aimed at addressing climate risks, given that weather—good or bad—is often viewed as a manifestation of divine intervention. Together, the chapters presented in this section of the book provide insights into the social considerations and scientific approaches that inform the adoption of CSA.

Because technologies are only part of the food system, the fourth set of chapters explores how value chains contribute to the climate-resilience of smallholder farmers and how climate risks to these value chains can be reduced. Barzola et al. focus on farmers and test the hypothesis that farmer entrepreneurship—the innovative use of agricultural resources to create opportunities for value creation—as well as engagement in the value chain facilitates the adoption of CSA technologies. The study found that farm size influences entrepreneurial innovativeness in a surprising way—with smaller farms more likely than larger ones to engage in all forms of innovation. Actors seeking to promote innovation, including the adoption of technology, might therefore consider investing in programmes that help farmers to develop a more entrepreneurial outlook. Hammond et al. further explore farmer participation and climate resilience. The authors use an innovative survey tool, the Rural Household Multi-Indicator Survey, to investigate how participation in *Shea* value chain activities benefit poor farmers. *Shea* trees serve as a buffer against desertification, accumulate carbon in the landscape and protect soil and water resources, while processing activities (more specifically, *shea* butter production)

can increase farmers' adaptive capacity by boosting incomes. In contrast, Sloan et al. examine how private-sector firms, in different parts of the supply chain, view, understand and engage with climate change and the promotion of CSA technologies. The key factors influencing the readiness of companies to incorporate CSA into their strategies were found to be specialised staff and a track record of actively promoting sustainability within the company. The scientific community therefore needs to provide actionable information to incentivise companies' investments in CSA; particularly emphasising returns on investment and the cost of inaction. Mwongera et al. discuss the need to link climate change analyses with value chain approaches in designing CSA interventions. Using a case study from Nyandarua County in Kenya, the authors illustrate how the climate risk profile (CRP) approach supports identification of major climate risks and their impacts on the value chain, identifies adaptation interventions, and promotes the mainstreaming of climate-change considerations into development planning at the subnational level. They conclude that the magnitude of a climate risk varies across value chains. Allen and de Brauw take an even broader perspective to explore mechanisms that promote nutrition-sensitive value chains, as part of efforts to manage climate risks and increase resilience through diversification. Access to improved, biofortified seeds, reducing post-harvest loss (for example, through adequate storage and the transportation of perishable crops), and diet diversification are key value-chain interventions for improved nutrition. Vermulen considers the very big picture, describing recent private-sector progress towards realising CSA targets. The author looks at the Climate-Smart Agriculture Initiative of the WBCSD and shows that the global agri-food sector is exceeding WBCSD targets for global food production, but falling short on emissions reductions, and failing to track outcomes for farmers' livelihoods. There are major gaps in information, monitoring, reporting and verification which need to be tackled if the ambitious CSA targets are to be met. Overall, this section of the book highlights the instrumental role of systemic, collective action for promoting climate-smart value chains.

In order to meet global food security ambitions, CSA technologies need to be accessible and accessed by farmers. The final section of the book discusses mechanisms for bringing CSA to scale. Franzel et al. explore farmer-to-farmer extension systems and find that these approaches can significantly increase the pool of farmers adopting CSA practices, but that this varies across practices and contexts. Their chapter suggests that this innovative advisory approach should not replace traditional, low-performing extension services, but rather complement existing approaches (such as extension campaigns, farmer field schools or information and communication technology). Acosta et al. study the role of multi-stakeholder platforms in promoting an enabling policy environment for climate action. These platforms can create ownership, knowledge and science-policy dialogue at various scales. In a similar vein, Kadzamira et al. discuss the role of different partnership arrangements in scaling CSA in Zambia, Zimbabwe and Malawi. Accordingly, successful partnerships for scaling build on existing structures and mechanisms, bring mutual benefits for all stakeholders, and ensure transparency in decision-making processes. Finally, Ruben et al. investigate the different rural financial instruments

that are available for promoting CSA. While the adoption of practices and technologies may be stimulated through interventions that address very specific resource constraints (through credit, insurances, and input provisions, for example), scaling CSA requires more systematic investments (for example, blended mechanisms) that allow for increases in farm income while minimising risks.

1.3 Implications for Development

This book highlights a wide cross-section of effort to design and disseminate agricultural technologies and approaches that help farmers better cope with climate risks. During a review of the chapters, however, several common gaps were identified that may merit attention in future research.

The main climate risk considered in these pages is drought—an obvious choice, given the long history of efforts to identify technologies suitable for drought-affected regions of Africa. Drought is already endemic in large parts of eastern and southern Africa. A principal concern is that these areas will expand as the climate continues to change. However, there is relatively little discussion about the variation in drought across the region and how this is expected to alter over time. This is based on the assumption that current drought risks are indicative of weather patterns under a changing climate. Yet it is not obvious that current drought risks will simply expand spatially. Over the next generation or two, the types of drought may change (cf. Chavez et al. 2015). A larger proportion of farmers may find that the rains start late or end earlier, or that the seasons simply shorten. In some areas, mid-season dry spells affecting flowering may become more common. This points to a need to better characterise how drought risks are likely to change over time and, more explicitly, account for this in technology design.

While rising average temperatures are linked with the likely spread of drought, the chapters in this book suggest that comparatively little work has been completed on solutions to these temperature changes. This is surprising given the irrefutable evidence that temperatures are rising in line with the growth of GHGs, and may be rising faster in sub-Saharan Africa than in other parts of the world. Higher average temperatures are widely expected to shift the incidence of pests and diseases affecting crop and livestock production (Bett et al. 2017). However, models tracking the speed and incidence of this change remain rudimentary. Observers note that rising temperatures may also affect plant flowering and fruit production, as well as the timing and severity of drought. But the thresholds for these changes do not seem to be well defined in applied technology development programmes. If scientists remain uncertain about the levels, spatial distribution and timing of changing temperatures, designing technology suitable for the diverse farming systems of eastern and southern Africa will continue to be challenging.

Similarly, solutions to the endemic and possibly worsening climate risk of flooding are almost totally absent in this collection of studies. This includes the need to

develop varieties that are more tolerant of water-logging and to strengthen water management and control systems.

Most of the chapters concentrate on the improvement of technologies and management strategies for coping with today's climate risks. This is understandable, given the pressing need to improve the productivity of farming systems. The emphasis is, therefore, on technologies that help farmers to better cope with today's risks, which are also likely to support larger numbers of farmers who may be affected by a changing climate in the future. As such, this body of work may be better characterised as 'climate-risk management' rather than 'climate change management'. But given that it can take several decades to develop a new crop or livestock variety, some investment needs to be allocated to coping with changes likely to occur over the next generation or two. And the possible differences between today's climate risks and the probable changes in these risks over time needs to be more consistently acknowledged.

Finally, while the focus of these papers has been on climate risks, greater attention needs to be directed to the trade-offs in household decision-making that may lead many farmers to identify climate risks as secondary. Indeed, market risks—such as price and quality—may be more important than climate risks in regions benefiting from the expansion of commercial opportunities. Even in drought-prone regions, such as those growing cotton or sunflower or livestock, farmers may be willing to adopt technologies offering moderate risks and larger potential returns. Similarly, efforts to reduce market risks may allow farmers to experiment with a wider range of productivity-enhancing technologies. Ideally, every new technology will offer higher yields as well as lower risks, including climate risks. In practice, the distribution of technology traits will continue to vary for different environments.

Ultimately, these papers highlight the increasing attention being given by agricultural research and extension officers operating in eastern and southern Africa to problems of climate risk and the threats of climate change. Most of the chapters in this book emphasise concerns around technology targeting, dissemination and scaling up needed to speed the adoption of improved practices. The challenge remains to achieve faster gains on the ground. More evidence-based examples of scale up are therefore needed, along with greater attention on documenting and sharing lessons from successful and unsuccessful practices.

Next year, CSA will turn ten. The development community must face the existential question of whether it will be time to celebrate? Only 2 years remain before countries need to report progress towards implementing their Nationally Determined Contributions that are at the heart of the Paris Agreement—virtually all of which identify improving agricultural practices in Africa as a priority under climate change. And only 12 years remain before the 2030 deadline set by the United Nations Framework Convention on Climate Change to have 500 million climate-smart farmers. How can we best combine our future efforts to achieve this target?

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