# A Practical Guide to Climate-Smart Agriculture Technologies in Africa

Working Paper No. 224

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

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RESEARCH PROGRAM ON
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**Photos:**

# Abstract

Climate-smart agriculture (CSA) has been promoted since 2011 to increase productivity, improve resilience to climate variability and change and reduce greenhouse gas emission, where feasible, in farming systems globally and especially in Sub-Saharan Africa. CSA is unique, by comparison, to some other agricultural development approaches because it is outcome oriented, explicitly considers synergies and trade-offs among food and environment objectives and promotes solutions relevant to specific times and places. These advances however complicate CSA programming and investments. Such a flexible framework often leaves policy makers and program developers asking *what is and what is not climate-smart*? This guide provides a simple qualitative planning tool to help answer that question. With the information compiled here based on expert survey, users can conduct a rapid appraisal of the 'climate-smartness' of management practices and technologies. Specifically, users can explore suggested management practices and technologies based on (1) climate risks they address, (2) constraints to adoption and (3) potential impacts on productivity, resilience and mitigation when changing management of cereal-, paddy rice-, tree-, livestock- and fish-based systems. These three characteristics of risks, constraints and outcomes represent a minimum level of information to consider when deciding whether a technique is climate-smart or not and potential concerns or opportunities. The document concludes with a compilation of technical manuals and extension guides on practices to provide user instructions on implementing technologies in the field.



**Keywords**

Climate-smart agriculture; climate risk; decision guide; barriers to adoption

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# Contents

# Acronyms

| | |
|---|---|
| AUC | Africa Union Commission |
| CA | Conservation Agriculture |
| CCAFS | Climate Change, Agriculture and Food Security |
| CIAT | International Center for Tropical Agriculture |
| CIMMYT | International Center for Wheat and Maize Improvement |
| $CO_2eq$ | Carbon dioxide equivalent |
| CSA | Climate-Smart Agriculture |
| FAO | United Nations Food and Agriculture Organization |
| GHG | Greenhouse Gas |
| ICRAF | World Agroforestry Centre |
| NEPAD | New Partnership for Africa’s Development |
| NPK | Nitrogen, Phosphorous and Potassium Fertilizer |
| NGO | Non-Governmental Organization |
| P4S | Partnerships for Scaling Climate-Smart Agriculture |

# Introduction

Climate-smart agriculture (CSA) refers to agriculture that delivers: (1) sustainable increases in food production, availability and productivity, (2) increases in resilience to climate change and/or adaptive capacity of farms and (3) accumulates carbon in soils or biomass or reduces emissions of greenhouse gases when possible (Neufeldt *et al.*, 2013; Lipper *et al.*, 2014). CSA therefore aims to address food security and climate change goals simultaneously. That integration, of climate into the food security and development agenda, is fundamental to CSA. Without explicit consideration, projects, programs and policies advocating a shift in agricultural management are promoting agricultural development (a worthwhile goal), but not climate-smart agricultural development.

Outcomes drive CSA. In contrast to many previous agricultural development initiatives, CSA begins with the end-goals rather than the mechanisms to get there. Technologies ranging from soil management to climate information services may be considered CSA if they achieve the desired food security and climate change adaptation and mitigation outcomes (FAO, 2013). The lack of prescription, combined with the multi-objective and multi-outcome oriented approach, creates an inclusive framework for agricultural development. This has also led to some confusion, which requires guidelines for its implementation. Actors with different value systems can address overarching and common goals—food security and climate change—together and in ways relevant to their own priorities and contexts.

However, this flexibility of CSA to include essentially any intervention that achieves the intended productivity, resilience and mitigation outcomes leaves scientists, development practitioners, civil society and policy makers asking an existential question: *what is and what is not CSA?* (Rosenstock *et al.*, 2015a). The answer unsurpringly not straightforward and opinions vary (Box 1). CSA is subject to the values and priorities of farmers, communities, governments, etc. and therefore what is considered CSA is specific to the place both in location and time. Many interventions may be climate-smart somewhere, but few are climate-smart everywhere. And, what may be climate-smart today may not be climate-smart tomorrow given the dynamic nature of agriculture, climate and society (Rosenstock *et al.*, 2015b).

Agricultural interventions are inherently context specific, with yields, soil health, economics and adoption responses varying under different social and environmental conditions (Bayala *et al.*, 2012; Pittelkow *et al.*, 2014; Giller *et al.*, 2015; Cheesman *et al.*, 2016). The importance of local factors to intervention performance and outcomes comes intuitively to most development practitioners and policy makers. However, considering multiple objectives simultaneously and explicitly, is often less intuitive. Policy institutions, iNGOs, donors and governments have asked for a simple guide to help understand and evaluate when technologies are likely or are likely not to be climate-smart to assist with planning CSA programming and investments (Bwalya, 2015). This 'practical guide' is a direct response to that request.

This document provides a qualitative assessment of the impact field and farm-level technologies have on performance indicators of CSA across a range of agricultural contexts. Actual performance for any intervention and outcome combination will vary and depend on local factors, as described above. However, the information found here provides a first indication to understand the synergies potentially captured or trade-offs likely to be encountered in implementing CSA. It does not intend to be a definitive analysis. Instead, our objective is to draw attention to the nuance that one might want to consider when designing CSA programs and policies, or when assessing changes to farming practices with farmers.

Therefore, the document should not be seen as the end solution, but rather as an instrument to inform CSA dialogues.

**Box 1: Select opinions on what is ‘climate-smart’?**

In short, climate-smart agriculture aims to meet three objectives: productivity, resilience/adaptive capacity and mitigation. For each of the three objectives, implementation of improved crop or livestock management interventions will result in either an increase, decrease or no change (signs) in that objective. Three objectives x three possible outcomes means that ther are 3’ or 27 unique possible combinations for any proposed CSA practice. But fundamentally, CSA intends to create synergies and ‘triple wins’ across the three pillars. Therefore, if we limit ourselves to outcomes where there are least non-negative outcomes across all three pillars, there are only 8 possible outcomes that are climate-smart. That is, for example, one where productivity *increases*, resilience *increases* and there is *no change* in mitigation. Or another where there is *no change* in productivity, resilience increases and there is *no change* in mitigation. This can be merged with the idea that CSA is time and place specific to define climate-smartness *for this report* as an agricultural technology, practice or intervention that achieves one of the 8 possible outcomes for a farming system in a specific place (T. Simons pers. com.).

Following the logic of the FAO definition (FAO 2013), we ought to be able to measure a contribution to productivity growth, resilience and mitigation. However, it is a rare technology that would meet all three criteria. We should not expect this. And virtually all technologies have their main goal as raising productivity (however this is defined). If the aim is to respond to *climate change* (and thus be climate smart) then the productivity objective must be combined with the mitigation objective or with the resilience objective. Either a technology contributes to the reduction of GHG - mitigation. Or a technology helps farmers improve their production in the face of rising temperatures and/or changing precipitation patterns – resilience. Or both. The judgement of these mitigation and adaptation contributions requires clear measures of i) the reduction of GHG, and/or ii) improved tolerance to rising temperatures, and/or iii) improved tolerance to a changing pattern of precipitation caused by climate change – such as drought. While the mitigation of GHG is relatively easy to measure, in most cases smallholders have little incentive to invest in meeting this societal goal. Few experiments consider measuring the impacts of rising temperatures. We would expect most work on the sub-set of challenges relating to drought, because this is both a current problem, and one that may worsen in the future. A smaller set of studies may deal with the problems of flood (D. Rohrbach pers. com.).

Understanding the climate-smartness of interventions though is just the beginning for implementation. Equally, or more important, is the ‘how-to’ for interventions. There is an abundance of technical guides available for smallholder farming settings that dominate Sub-Sharan Africa. We compiled technical guides readily accessible on the internet as a resource for implementers, as produced by the respective organizations such as CGIAR and Non-Governmental Organizations (NGOs).[1] This is by no means a comprehensive bibliography; it is simply one of a number of knowledge resources.

This guide intends to provide users with a planning tool for rapid assessment of the ‘climate-smartness’ of select crop and animal production practices for Sub-Saharan Africa in two ways. One, it can serve as a quick reference to answer questions about how specific management practices affect key indicators of productivity, resilience and mitigation (potential impacts) and the potential constraints to adoption for scaling up of the interventions. Two, the guide can be used to generate a list of promising management options that meet the criteria and priorities of stakeholders.

## Methods

The guide is presented as a series of three Tables for five farming systems (see Appendices 1-5). Farming systems are considered based on the primary componenet: cereal, paddy rice, trees, livestock and fish. Each table displays the relationships between a set of management

[1] Inclusion or exclusion of implementation materials in this practical guide does not represent an implicit or explicit value judgment on its quality by authors, CCAFS or partner institutions. Questions about the materials should be directed to the original authors. Please forward links to additional materials to the corresponding author of this paper so that the appendices can be updated as more information becomes available.

practices and either (1) mitigation of **climate risks**, (2) social and environmental **constraints to adoption** or (3) **CSA outcomes** including select indicators of productivity, resilience and mitigation. Below we explain how to interpret each of the tables.

## Climate Risks

Climate risks are weather-related production challenges that arise due to climate change and variability. These risks may negatively impact production in the future and in some cases, are already. Examples of climate risks are increased flooding, higher mean temperatures, shortened growing seasons and increased drought periods, etc (Thornton *et al.*, 2009; Schlenker & Lobell, 2010; Lobell *et al.*, 2011; Rowhani *et al.*, 2011; Notenbaert *et al.*, 2016). Relationships shown in the tables indicate whether the management practice or technology mitigates the specific risk. The tables utilize two factors, colors and symbols, to show the direction and magnitude of the impact of technologies on climate risks. Direction relates to whether a practice has a positive (ameliorating) or negative (exacerbating) impact on the climate risk. This is shown in the table with a color gradient and a symbol for positive (+ and blue) and negative (- and red), respectively (see key). Magnitude relates to the relative size of the expected effect on risk, whether significant or trivial. Magnitude is displayed in the tables by the intensity of the color in the gradient and the number of symbols (eg, ++ vs +), where more symbols is a larger impact. Both direction and magnitude are represented by *both* colors and symbols so that it is easy to visually detect patterns (colors) and so that it is clearly discernable when printed in black and white (symbols).

## Constraints to adoption

The second table relates management practices and technologies to social and environmental constraints to implementation. Constraints are characteristics of farms, farming systems, the environment and broader social conditions that influence the likelihood of a change in practice. For example, the presence of livestock may limit the adoption of conservation agriculture (Giller *et al.*, 2009) or insecure land tenure may restrict the use of trees on farm or growth of fodder for livestock (Scherr & Müller, 1991; Sumberg, 2002). Compilations of the constraints for adoption of single practices show highly context-specific results, with the direction and magnitude of affect often being inconsistent (Knowler & Bradshaw, 2007). We utilize the same two-factor coding (color & symbols) used in the climate risks tables to show whether the socioeconomic factor increases (+ and blue) or decreases (- and red) the likelihood of successful adoption of that particular CSA practice in that context. The number of symbols and intensity of color reflect the importance of that factor as a constraint (-, --) or enabling (+, ++) factor.

## CSA Impacts

The third tables presents the CSA impacts, or the outcomes that farm management practices have on livelihoods and the environment, specifically crop or animal productivity, resilience and mitigation. CSA impacts can be and are most often described at the aggregate level of the three outcomes (productivity, resilience or mitigation). In this guide, the high-level outcomes are disaggregated into more specific outcomes. For example, productivity can be represented by yield, but also economics and labor. Resilience is the most challenging and controversial outcome to measure (Walker *et al.*, 2006; FAO, 2015). This guide takes a practical approach to the evaluating the impact of management on system resilience, by use of proxies. We use factors that theory suggests improves either the buffering capacity of systems or increases the ability for systems to respond to shocks. This includes attributes of physical resilience such as soil carbon, which improve chemical and physical properties of soil (Paustian *et al.*, 2016), social resilience such as women's labor, which affects nutrition and livelihoods outcomes (Beuchelt & Badstue, 2013), and economic resilience such as resource use efficiency or diversification (Barrett *et al.*, 2001). Perhaps more than productivity or resilience, assessing the impact on mitigation outcomes is straightforward because there are limited number of metrics related to key processes of interest. This guide therefore evaluates the impact of management on the major pathways that change the exchange of greenhouse gases, including carbon dioxide, between plants, animals, soils and the atmosphere. Again, we utilize a two-factor coding (color & symbols) as in the previous tables to show whether the constraint to adoption (columns) increases (+) or decreases (-) the likelihood of using the practice.

## Data Collection

Values in the tables were based on expert opinion of research scientists within the CGIAR system and a review of literature found in the CSA Compendium (Rosenstock et al. 2015a). The survey was created with Google Forms and distributed to 15 scientists with technical knowledge of the farming systems and the technologies and management practices of interest. Scientists were advised to only respond about practices within their domain of expertise. The survey asked for qualitative responses relating the technologies to climate risks, constraints to adoption or CSA impacts. Answers were compiled and average response was recorded for each. These values were crosschecked against literature found in a comprehensive compilation of scientific literature on agricultural research in Africa.

# How to use this guide: a checklist for planning

Climate risks, impacts and constraints to adoption are a minimum level of information one might consider when assessing potential of CSA interventions. There are many ways in which these factors are being or have been evaluated ranging from meta-analysis (Rosenstock *et al.*, 2015a) to field research (Arslan *et al.*, 2015; Mwongera *et al.*, 2016). This guide promotes a complementary approach, a straightforward stepwise process.

The checklist-like process looks up technologies or management practices by farming system in the tables provided in the Appendices, filtering through the climate risks and factors constraining adoption. The checklist only has three questions:

1. Does the management practice or technology mitigate the climate risk of interest?
2. Are there social or environmental factors in the farming system that may constrain the adoption of the management practice or technology?
3. Does the management practice or technology maximize the outcomes and priorities of interest?

These results can provide users a point of reference of potential issues to consider in program and/or help select best-fit technologies. Below we describe each step in more detail.

**Step 1. Farming system**

Note we assume that the user has a target farming system or agricultural product in mind and information on the potential climate risks that a particular system faces prior to beginning.

**Step 2. Climate risks**

The first step is to look at 'climate risk' tables in Appendices 1-5 to identify the potential practices that would mitigate the climate risks already identified. Practices are not typically relevant to all risks. The uniqueness of the risk mitigation potential for each practice underscores the importance of understanding the potential climate risks prior to starting. Each Table focuses on climate risks in a single farming system. The climate risks are provided along the top of the table and the practices in the left-hand column. Move from left to right for the selected climate risks. Practices marked with a blue box or + sign indicate practices that address the given climate risk while practices with a red box or - sign indicate they do not. Uncolored boxes with a +/- sign indicate practices that either do not address the climate risks or there is not enough known to make a recommendation. Practices, which address the climate risk you have chosen, are possible to pass through to the next step.

**Step 3. Constraints to adoption**

Even if the technology or practice will hypothetically help address climate and weather related risks, it is not a good candidate for promotion if it is not appropriate for the farming system. Many factors—both social and environmental—affect the likelihood of adoption. Here we identify the major constraints that might impede success. The key factors are identified at the top of the tables in the relevant 'constraint tables' and the practices in the first column. For each practice selected for evaluation based on the previous step, identify which of the socioeconomic conditions are present for a farmer in the respective region. Follow the column of the table from top to bottom to see if these socioeconomic conditions are suitable for the given practice. The sub-set of practices that are unlikely to have significant contraints in the region of interest represent a menu of possibly CSA practices appropriate for the given farmer.

**Step 4. CSA Impacts**

Farmers and communities are heterogeneous. They have different priorities, goals and desires. In some cases, farmers may be interested in maximizing productivity while others economic resilience and so on. In the final step it is important to examine the sub-set of practices from Step 3 against their likely impacts for the farmers and farming systems. Here, it is important to incorporate the priorities of the communities and stakeholders to filtered out what practices should remain. The ‘csa impact' tables in the Appendices detail a selection of possible outcomes from adoption. Here we suggest that the user identify a few priorities of what is important and then set threshold for the impacts. For example, economic returns are often the most important for farmers. Therefore, a user might only select practices that have + or ++ for economic returns. Then, the user can use these thresholds to filter out practices that do not meet the necessary criteria.

## Conclusion/recommendations

NEPAD and the United Nations Food and Agriculture Organization (FAO) convened a technical working group to draft a practical guide about selection, implementation and extension during a three-day workshop in May 2015. This document represents an output of the 2$^{nd}$ section on implementation. Instead of remaking technical guides, we decided to provide an accessible resource for framing practice selection discussions and a compilation of many of the technical guides that have already been published and are readily available on line.

The appendicies were created based on a survey of scientists. The final outcomes was not without contention. Rarely were the responses unanimous, but this may have been expected given the context specificity of CSA. Thus, we also expect that some readers will disagree with the characterization based on their own experiences or reading. Our effort could greatly be improved by crowd sourcing experiences. Often the responses tended to go toward central tendancy as respondents rarely pick extremes. Crowd sourcing a greater number of responses from a larger and more diverse set of experiences would help the community converge on responses rapidly.

One of the major surprises of this work was the availability of well written and thorough guides for extension agents, many of which were found by searching CGIAR institution websites. So why do development partners continue to request these? Outdated, poor communication, or shifting priorities? We have made a initial compilation in the Appendix 6 with active links. However, this is just the tip of the iceberg. Modernizing this resource to merge similar resources together and create a clearing house, where everyone not only goes to find the technical guide they need but also to post the technical guides they have produced, would be a significant step forward toward coherence and reducing repetitive work.

This information has been continuously requested by development partners. Simple analyses and steps such as those presented here can help move information from the scientific into the development spheres of influence, which is critical given the significant opportunity for CSA to impact on food and climate issues affecting billions. The research for development community would do well to further embrace principles of working with the best information available in more iterative processes. Development practitioners require information today. We must package our knowledge in a timely manner and in the right format.

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# Appendix 1: Cereal-based systems

Table 1.1: Climate risk mitigation in cereal-based systems.

| **Cereal-based** | **Climate Risks** | | | | |
|---|---|---|---|---|---|
| **Practices** | Increased growing season temperature | Intra-seasonal droughts | Shortening of growing seasons | Unpredictable seasons | Increased rainfall intensity |
| | Land Preparation | | | | |
| Reduced tillage | + | + | + | +/- | - |
| No till | ++ | + | ++ | +/- | - |
| | Soil Amendments | | | | |
| Integrated soil fertility management | +/- | +/- | +/- | +/- | +/- |
| Biochar | +/- | +/- | +/- | +/- | +/- |
| Green manure | + | +/- | +/- | +/- | + |
| Compost | + | +/- | + | +/- | + |
| Inorganic Inputs (NPK) | +/- | +/- | +/- | +/- | +/- |
| Organic + Inorganic Inputs | + | + | + | +/- | + |
| | Fertilizer Application Methods | | | | |
| Fertilizer banding | - | +/- | +/- | +/- | +/- |
| Microdosing | - | +/- | +/- | +/- | +/- |
| | Diversification | | | | |
| Crop rotations | +/- | +/- | +/- | +/- | +/- |
| Intercropping with Legumes | +/- | +/- | +/- | +/- | +/- |
| | Water Management | | | | |
| Mulching | + | ++ | ++ | + | ++ |
| Drip Irrigation | +/- | ++ | ++ | +/- | - |
| Deficit Irrigation | +/- | ++ | ++ | +/- | - |
| Zai pits | +/- | + | + | +/- | +/- |
| Partial root zone drying | +/- | + | + | +/- | +/- |
| Stone bunds | +/- | + | + | +/- | + |
| Fanya juus | +/- | +/- | +/- | +/- | +/- |
| Dead level contours | +/- | +/- | +/- | +/- | +/- |
| Water harvesting | + | + | + | +/- | +/- |
| | Miscellaneous | | | | |
| Conservation Agriculture (CA) | + | + | + | + | + |
| On-time planting | + | + | +/- | +/- | +/- |
| Planting in rows | +/- | +/- | +/- | +/- | +/- |
| Improved varieties (drought/pest tolerance) | +/- | + | + | +/- | +/- |
| Integrated Pest Management (IPM) | +/- | +/- | +/- | +/- | +/- |

Table 1.2: Constraints to adoption of CSA in cereal-based farming systems.

| **Cereal-based** | Socioeconomic Factors | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Practices** | Access to finance | Land tenure | Access to ext. services | Access to market info. | Labour avail. | Access to Transport. | Livestock pressure | Off-farm jobs | Access to irrigation |
| | Land Preparation | | | | | | | | |
| Reduced tillage | +/- | + | +/- | +/- | - | +/- | - | - | +/- |
| No till | +/- | + | +/- | +/- | - | +/- | - | - | +/- |
| | Soil Amendments | | | | | | | | |
| Integrated soil fertility management | + | +/- | ++ | + | + | +/- | -- | - | +/- |
| Biochar | + | +/- | +/- | +/- | +/- | +/- | -- | - | +/- |
| Green manure | +/- | +/- | + | - | + | +/- | -- | - | +/- |
| Compost | +/- | +/- | + | +/- | ++ | +/- | -- | - | +/- |
| Inorganic Inputs (NPK) | ++ | + | + | + | +/- | +/- | +/- | + | +/- |
| Organic + Inorganic Inputs | + | + | + | + | + | +/- | -- | - | +/- |
| Fertilizer banding | + | + | + | + | +/- | +/- | +/- | +/- | +/- |
| Microdosing | + | + | + | + | +/- | +/- | +/- | +/- | +/- |
| | Fertilizer Application Methods | | | | | | | | |
| Crop rotations | +/- | +/- | +/- | +/- | +/- | +/- | - | +/- | +/- |
| Intercropping with Legumes | +/- | +/- | +/- | +/- | +/- | +/- | - | +/- | +/- |
| | Water Management | | | | | | | | |
| Mulching | +/- | +/- | +/- | +/- | + | +/- | -- | - | +/- |
| Drip Irrigation | ++ | +/- | + | + | +/- | +/- | +/- | +/- | +/- |
| Deficit Irrigation | ++ | +/- | + | + | +/- | +/- | +/- | +/- | +/- |
| Zai pits | +/- | +/- | + | +/- | ++ | +/- | + | - | +/- |
| Partial root zone drying | +/- | +/- | + | +/- | +/- | +/- | +/- | +/- | +/- |
| Stone bunds | + | + | + | +/- | ++ | +/- | +/- | + | +/- |
| Fanya juus | + | + | + | +/- | + | +/- | +/- | + | +/- |
| Dead level contours | + | + | + | +/- | + | +/- | +/- | + | +/- |
| Water harvesting | +/- | +/- | + | +/- | + | +/- | +/- | +/- | + |
| | Miscellaneous | | | | | | | | |
| Conservation Agriculture (CA) | + | +/- | + | + | + | +/- | -- | + | +/- |
| On-time planting | +/- | +/- | +/- | +/- | + | +/- | +/- | - | +/- |
| Planting in rows | +/- | +/- | + | + | + | +/- | +/- | +/- | +/- |
| Improved varieties (drought/pest tolerance) | ++ | +/- | +/- | +/- | +/- | +/- | +/- | + | + |
| Integrated Pest Management (IPM) | +/- | +/- | + | | + | +/- | +/- | + | +/- |

Table 1.3: Impacts of CSA practices on select indicators of productivity in cereal-based farming systems.

| **Cereal-based** | **Indicators of Productivity** | | | | | |
|---|---|---|---|---|---|---|
| **Practices** | Yield | Variability | Labour | Income | Labor by women | Income of women |
| | Land Preparation | | | | | |
| Reduced tillage | +/- | + | - | +/- | ++ | +/- |
| No till | +/- | + | - | +/- | ++ | +/- |
| | Soil Amendments | | | | | |
| Integrated soil fertility management | + | + | - | + | ++ | +/- |
| Biochar | +/- | +/- | - | - | ++ | - |
| Green manure | + | + | - | +/- | + | +/- |
| Compost | + | + | - | +/- | + | +/- |
| Inorganic Inputs (NPK) | + | + | +/- | - | +/- | +/- |
| Organic + Inorganic Inputs | ++ | ++ | - | + | + | - |
| | Fertilizer Application Methods | | | | | |
| Fertilizer banding | + | +/- | +/- | +/- | +/- | +/- |
| Microdosing | + | + | +/- | +/- | +/- | +/- |
| | Diversification | | | | | |
| Crop rotations | + | + | +/- | +/- | +/- | +/- |
| Intercropping with Legumes | + | + | +/- | + | +/- | +/- |
| | Water Management | | | | | |
| Mulching | + | + | - | - | + | +/- |
| Drip Irrigation | + | + | - | - | +/- | - |
| Deficit Irrigation | + | + | - | - | +/- | - |
| Zai pits | + | + | -- | - | + | +/- |
| Partial root zone drying | +/- | +/- | +/- | +/- | +/- | +/- |
| Stone bunds | +/- | +/- | -- | -- | + | - |
| Fanya juus | +/- | +/- | -- | - | + | +/- |
| Dead level contours | +/- | +/- | - | - | + | +/- |
| Water harvesting | + | + | - | - | +/- | +/- |
| | Miscellaneous | | | | | |
| Conservation Agriculture (CA) | + | + | - | +/- | ++ | - |
| On-time planting | + | + | +/- | + | +/- | +/- |
| Planting in rows | + | + | - | + | +/- | +/- |
| Improved varieties (drought/pest tolerance) | + | + | +/- | +/- | +/- | - |
| Integrated Pest Management (IPM) | + | + | +/- | +/- | + | +/- |

Table 1.4: Impacts of CSA practices on select indicators of resilience in cereal-based farming systems.

| **Cereal-based** | **Indicators of Resilience** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Practices** | Farm level biodiversity | Groundwater availability | Soil Erosion | Plant available nutrients | Infiltration of water into the soil | Soil microbial diversity | Soil aggregation | Soil water holding capacity |
| | Land Preparation | | | | | | | |
| Reduced tillage | +/- | + | + | +/- | + | + | + | +/- |
| No till | +/- | +/- | + | +/- | + | + | + | +/- |
| | Soil Amendments | | | | | | | |
| Integrated soil fertility management | + | +/- | + | + | + | + | + | +/- |
| Biochar | +/- | +/- | +/- | + | +/- | +/- | +/- | +/- |
| Green manure | + | +/- | + | + | + | + | + | +/- |
| Compost | +/- | +/- | + | ++ | + | ++ | + | +/- |
| Inorganic Inputs (NPK) | +/- | +/- | +/- | + | +/- | - | - | +/- |
| Organic + Inorganic Inputs | +/- | +/- | + | ++ | + | + | ++ | + |
| | Fertilizer Application methods | | | | | | | |
| Fertilizer banding | +/- | +/- | +/- | + | +/- | +/- | +/- | +/- |
| Microdosing | +/- | +/- | +/- | + | +/- | +/- | +/- | +/- |
| | Diversification | | | | | | | |
| Crop rotations | + | +/- | + | + | +/- | + | + | +/- |
| Intercropping with Legumes | + | +/- | + | + | +/- | + | + | +/- |
| | Water Management | | | | | | | |
| Mulching | +/- | +/- | ++ | + | ++ | + | + | + |
| Drip Irrigation | +/- | - | +/- | +/- | +/- | +/- | +/- | +/- |
| Deficit Irrigation | +/- | - | +/- | +/- | +/- | +/- | +/- | +/- |
| Zai pits | +/- | +/- | + | + | + | +/- | +/- | +/- |
| Partial root zone drying | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| Stone bunds | +/- | + | ++ | +/- | ++ | +/- | +/- | +/- |
| Fanya juus | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| Dead level contours | +/- | + | + | +/- | + | +/- | +/- | +/- |
| Water harvesting | +/- | + | + | +/- | + | +/- | +/- | +/- |
| | Miscellaneous | | | | | | | |
| Conservation Agriculture (CA) | + | +/- | + | + | + | + | + | +/- |
| On-time planting | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| Planting in rows | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| Improved varieties (drought/pest tolerance) | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| Integrated Pest Management (IPM) | + | +/- | +/- | +/- | +/- | + | +/- | +/- |

Table 1.5: Impacts of CSA practices on mitigation indicators in cereal-based farming systems.

| **Cereal-based** | **Indicators of Mitigation** | | | | | |
|---|---|---|---|---|---|---|
| **Practices** | Changes in land use | Emissions from inputs | Carbon sequestered in soil | Carbon sequestered in biomass | N2O emissions | CH4 emissions |
| | Land Preparation | | | | | |
| Reduced tillage | + | + | + | +/- | + | +/- |
| No till | + | + | + | +/- | + | +/- |
| Soil Amendments | | | | | | |
| Integrated soil fertility management | - | + | + | + | - | +/- |
| Biochar | +/- | + | +/- | +/- | - | +/- |
| Green manure | + | + | + | +/- | + | +/- |
| Compost | - | + | + | +/- | + | - |
| Inorganic Inputs (NPK) | +/- | + | - | +/- | - | +/- |
| Organic + Inorganic Inputs | - | + | + | +/- | - | - |
| | Fertilizer Application Methods | | | | | |
| Fertilizer banding | + | + | +/- | +/- | - | +/- |
| Microdosing | + | + | +/- | +/- | - | +/- |
| | Diversification | | | | | |
| Crop rotations | + | + | +/- | +/- | +/- | +/- |
| Intercropping with Legumes | + | + | + | +/- | +/- | +/- |
| Mulching | + | + | + | +/- | + | - |
| Drip Irrigation | - | + | +/- | +/- | - | +/- |
| Deficit Irrigation | - | + | +/- | +/- | - | +/- |
| Zai pits | - | + | +/- | +/- | - | +/- |
| Partial root zone drying | + | +/- | +/- | +/- | +/- | +/- |
| Stone bunds | +/- | +/- | +/- | +/- | +/- | +/- |
| Fanya juus | +/- | +/- | +/- | +/- | +/- | +/- |
| Dead level contours | +/- | +/- | +/- | +/- | +/- | +/- |
| Water harvesting | +/- | +/- | +/- | +/- | +/- | +/- |
| | Miscellaneous | | | | | |
| Conservation Agriculture (CA) | - | + | + | + | + | +/- |
| On-time planting | +/- | + | +/- | +/- | +/- | +/- |
| Planting in rows | +/- | + | +/- | +/- | +/- | +/- |
| Improved varieties (drought/pest tolerance) | +/- | + | +/- | +/- | +/- | +/- |
| Integrated Pest Management (IPM) | +/- | +/- | +/- | +/- | +/- | +/- |

# Appendix 2: Lowland rice-based systems

Table 2.1: Climate risk mitigation in lowland rice-based systems.

| **Lowland Rice-based** | **Climate Risks** | | | | |
|---|---|---|---|---|---|
| **Practices** | Increased growing season temperature | Intra-seasonal droughts | Shortening of growing seasons | Unpredictable seasons | Increased rainfall intensity |
| | Soil Amendments | | | | |
| Integrated soil fertility management | + | + | + | + | +/- |
| Biochar | +/- | + | +/- | + | +/- |
| Green manure | +/- | + | +/- | + | +/- |
| Compost | +/- | + | +/- | + | +/- |
| Inorganic Inputs (NPK) | + | +/- | + | + | +/- |
| Organic + Inorganic Inputs | + | + | + | + | +/- |
| | Fertilizer Application Methods | | | | |
| Fertilizer banding | +/- | +/- | +/- | + | +/- |
| Microdosing | +/- | +/- | +/- | + | +/- |
| | Diversification | | | | |
| Crop rotations | +/- | + | +/- | + | +/- |
| Intercropping with Legumes | +/- | + | +/- | + | +/- |
| | Water Management | | | | |
| System of Rice Intensification (SRI) | + | ++ | + | + | +/- |
| Alternate wetting and drying (AWD) | +/- | ++ | +/- | + | +/- |
| Mid-season drainage | +/- | ++ | +/- | + | +/- |
| Improved varieties (drought/pest tolerance) | ++ | + | ++ | + | +/- |
| Integrated Pest Management (IPM) | +/- | +/- | +/- | + | +/- |

Table 2.2: Constraints to adoption of CSA in lowland rice-based farming systems.

| **Lowland Rice-based** | **Socioecological Factors** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Practices | Access to finance | Land tenure | Access to ext. services | Access to market info. | Labour avail. | Access to Transport. | Livestock pressure | Off-farm jobs | Access to irrigation |
| | Soil Amendments | | | | | | | | |
| Integrated soil fertility management | + | +/- | ++ | +/- | + | +/- | +/- | +/- | +/- |
| Biochar | + | + | ++ | +/- | + | + | +/- | - | +/- |
| Green manure | + | +/- | ++ | +/- | +/- | + | +/- | - | +/- |
| Compost | + | + | ++ | +/- | + | + | +/- | - | +/- |
| Inorganic Inputs (NPK) | + | +/- | ++ | +/- | + | +/- | +/- | +/- | +/- |
| | Fertilizer Application Methods | | | | | | | | |
| Organic + Inorganic Inputs | + | +/- | ++ | +/- | + | + | + | - | +/- |
| Fertilizer banding | + | +/- | ++ | +/- | +/- | +/- | +/- | +/- | +/- |
| | Diversification | | | | | | | | |
| Microdosing | + | +/- | ++ | +/- | +/- | +/- | +/- | +/- | +/- |
| Crop rotations | +/- | +/- | ++ | +/- | +/- | + | +/- | +/- | +/- |
| | Water Management | | | | | | | | |
| Intercropping with Legumes | + | +/- | ++ | + | + | + | +/- | - | +/- |
| System of Rice Intensification (SRI) | + | +/- | ++ | +/- | +/- | + | +/- | - | - |
| Alternate wetting and dryin (AWD) | + | + | ++ | +/- | +/- | +/- | +/- | - | - |
| Mid-season drainage | + | + | ++ | +/- | +/- | +/- | +/- | - | - |
| Improved varieities (drought/pest tolerance) | + | +/- | ++ | + | + | +/- | +/- | +/- | +/- |
| Integrated Pest Management (IPM) | + | + | ++ | +/- | +/- | +/- | +/- | - | - |

Table 2.3: Impacts of CSA practices on select indicators of productivity in lowland rice-based farming systems.

| **Lowland Rice-based** | **Indicators of Productivity** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Practices** | Increased growing season temperature | Yield | Variability | Labour | Income | Labor by women | Income of women |
| | Soil Amendments | | | | | | |
| Integrated soil fertility management | + | ++ | - | + | + | + | + |
| Biochar | +/- | + | - | ++ | + | ++ | + |
| Green manure | +/- | + | - | + | + | +/- | + |
| Compost | +/- | + | - | ++ | + | + | + |
| Inorganic Inputs (NPK) | + | ++ | +/- | +/- | + | +/- | + |
| Organic + Inorganic Inputs | + | ++ | - | + | + | + | + |
| | Fertilizer Application Methods | | | | | | |
| Fertilizer banding | +/- | ++ | +/- | +/- | + | +/- | + |
| Microdosing | +/- | ++ | +/- | +/- | + | +/- | + |
| | Diversification | | | | | | |
| Crop rotations | +/- | + | - | +/- | + | +/- | + |
| Intercropping with Legumes | +/- | + | - | + | + | + | + |
| | Water Management | | | | | | |
| System of Rice Intensification (SRI) | + | +/- | - | + | + | + | + |
| Alternate wetting and drying (AWD) | +/- | +/- | - | + | + | + | + |
| Mid-season drainage | +/- | +/- | - | + | + | + | + |
| Improved varieties (drought/pest tolerance) | ++ | ++ | - | - | + | +/- | + |
| Integrated Pest Management (IPM) | +/- | + | - | + | +/- | + | + |

Table 2.4: Impacts of CSA practices on select indicators of resilience in lowland rice-based farming systems.

| **Lowland Rice-based** | **Indicators of Resilience** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Practices | Farm level biodiversity | Groundwater availability | Soil Erosion | Plant available nutrients | Infiltration of water into the soil | Soil microbial diversity | Soil aggregation | Soil water holding capacity |
| | Soil Amendments | | | | | | | |
| Integrated soil fertility management | + | +/- | +/- | ++ | + | + | + | + |
| Biochar | +/- | +/- | +/- | + | + | + | + | + |
| Green manure | + | +/- | +/- | ++ | + | + | + | + |
| Compost | + | +/- | +/- | ++ | + | ++ | ++ | ++ |
| Inorganic Inputs (NPK) | +/- | +/- | +/- | ++ | +/- | +/- | +/- | +/- |
| Organic + Inorganic Inputs | + | +/- | +/- | ++ | + | + | + | + |
| | Fertilizer Application Methods | | | | | | | |
| Fertilizer banding | +/- | +/- | +/- | + | +/- | +/- | +/- | +/- |
| Microdosing | +/- | +/- | +/- | + | +/- | +/- | +/- | +/- |
| | Diversification | | | | | | | |
| Crop rotations | + | +/- | +/- | + | + | ++ | ++ | + |
| Intercropping with Legumes | + | +/- | +/- | + | + | ++ | ++ | + |
| | Water Management | | | | | | | |
| System of Rice Intensification (SRI) | +/- | + | +/- | +/- | +/- | ++ | + | +/- |
| Alternate wetting and drying (AWD) | +/- | + | +/- | +/- | +/- | + | +/- | +/- |
| Mid-season drainage | +/- | + | +/- | +/- | +/- | +/- | +/- | +/- |
| Improved varieties (drought/pest tolerance) | +/- | +/- | +/- | +/- | +/- | +/- | +/- | +/- |
| Integrated Pest Management (IPM) | - | +/- | +/- | +/- | +/- | - | +/- | +/- |

Table 2.5: Impacts of CSA practices on mitigation indicators in lowland rice-based farming systems.

| **Lowland Rice-based** | **Indicators of Mitigation** | | | | | |
|---|---|---|---|---|---|---|
| Practices | Changes in land use | Emissions from inputs | Carbon sequestered in soil | Carbon sequestered in biomass | N2O emissions | CH4 emissions |
| | Soil Amendments | | | | | |
| Integrated soil fertility management | +/- | + | + | + | + | +/- |
| Biochar | +/- | - | + | + | - | +/- |
| Green manure | +/- | - | + | + | + | +/- |
| Compost | +/- | - | +/- | + | - | +/- |
| Inorganic Inputs (NPK) | +/- | + | + | + | + | +/- |
| Organic + Inorganic Inputs | +/- | - | +/- | + | +/- | +/- |
| | Fertilizer Application Methods | | | | | |
| Fertilizer banding | +/- | - | +/- | + | - | +/- |
| Microdosing | +/- | - | + | + | - | +/- |
| | Diversification | | | | | |
| Crop rotations | +/- | +/- | + | + | +/- | +/- |
| Intercropping with Legumes | +/- | +/- | +/- | + | + | +/- |
| | Water Management | | | | | |
| System of Rice Intensification (SRI) | +/- | + | +/- | +/- | + | - |
| Alternate wetting and drying (AWD) | +/- | + | +/- | +/- | + | - |
| Mid-season drainage | +/- | + | +/- | +/- | +/- | - |
| Improved varieties (drought/pest tolerance) | +/- | - | +/- | + | +/- | +/- |
| Integrated Pest Management (IPM) | +/- | + | +/- | +/- | +/- | +/- |

# Appendix 3: Agroforestry systems

Table 3.1: Climate risk mitigation in agroforestry systems.

| **Agroforestry Systems** | **Addressing Climate Risks** | | | | |
|---|---|---|---|---|---|
| Practices | Increased growing season temperature | Intra-seasonal dreoughts | Shortening of growing seasons | Unpredictable seasons | Increased rainfall intensity |
| Boundary planting | ++ | +/- | + | + | + |
| Evergreen agriculture | ++ | + | + | + | ++ |
| Farmer managed natural regeneration | ++ | + | + | + | ++ |
| Multistrata | ++ | + | + | + | ++ |
| | Intercropping | | | | |
| Rows/alleys (N-fixing) | ++ | + | + | +/- | ++ |
| Rows/alleys (non-N-fixing) | ++ | + | + | + | ++ |
| Mixed (N-fixing) | ++ | +/- | +/- | + | ++ |
| Mixed (non-N-fixing) | ++ | +/- | + | + | ++ |
| Home gardens | + | +/- | + | + | + |
| Live fences | ++ | +/- | + | + | + |
| Parklands | ++ | +/- | + | + | + |
| Silvopasture | ++ | + | + | +/- | ++ |
| Woodlots | ++ | +/- | + | + | + |

Table 3.2: Constraints to adoption of CSA in agroforestry systems.

| **Agroforestry Systems** | **Socioecological Factors** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Practices | Access to finance | Land tenure | Access to ext. services | Access to market info. | Labour avail. | Access to Transport. | Livestock pressure | Off-farm jobs | Access to irrigation |
| Boundary planting | +/- | +/- | ++ | + | + | + | -- | +/- | +/- |
| Evergreen agriculture | + | +/- | ++ | ++ | + | + | -- | -- | +/- |
| Farmer managed natural regeneration | +/- | + | + | + | +/- | +/- | -- | +/- | +/- |
| Multistrata | +/- | +/- | ++ | + | + | + | -- | +/- | +/- |
| | Intercropping | | | | | | | | |
| Rows/alleys (N-fixing) | + | +/- | ++ | + | +/- | + | -- | -- | +/- |
| Rows/alleys (non-N-fixing) | + | +/- | ++ | + | +/- | + | -- | -- | +/- |
| Mixed (N-fixing) | +/- | +/- | ++ | + | + | + | -- | -- | +/- |
| Mixed (non-N-fixing) | +/- | +/- | ++ | +/- | + | + | -- | -- | +/- |
| Home gardens | +/- | +/- | + | +/- | + | +/- | -- | +/- | +/- |
| Live fences | + | +/- | + | + | + | + | -- | +/- | +/- |
| Parklands | +/- | +/- | +/- | +/- | + | +/- | +/- | +/- | +/- |
| Silvopasture | +/- | + | ++ | + | + | +/- | -- | +/- | +/- |
| Woodlots | + | +/- | ++ | ++ | + | + | -- | +/- | +/- |

Table 3.3: Impacts of CSA practices on select indicators of productivity in agroforestry systems.

| **Agroforestry Systems** | **Indicators of Productivity** | | | | | |
|---|---|---|---|---|---|---|
| Practices | Yield | Variability | Labour | Income | Labor by women | Income of women |
| Boundary planting | +/- | + | +/- | + | +/- | +/- |
| Evergreen agriculture | ++ | ++ | +/- | ++ | +/- | + |
| Farmer managed natural regeneration | + | ++ | +/- | + | +/- | + |
| Multistrata | +/- | ++ | - | + | +/- | + |
| | Intercropping | | | | | |
| Rows/alleys (N-fixing) | ++ | + | +/- | + | +/- | +/- |
| Rows/alleys (non-N-fixing) | +/- | + | +/- | +/- | +/- | +/- |
| Mixed (N-fixing) | ++ | + | + | + | +/- | +/- |
| Mixed (non-N-fixing) | +/- | + | +/- | +/- | +/- | +/- |
| Home gardens | + | + | + | + | +/- | + |
| Live fences | +/- | + | - | +/- | +/- | +/- |
| Parklands | + | + | + | + | +/- | ++ |
| Silvopasture | + | + | +/- | ++ | +/- | ++ |
| Woodlots | +/- | +/- | +/- | + | +/- | ++ |

Table 3.4: Impacts of CSA practices on select indicators of resilience in agroforestry systems.

| Agroforestry Systems | Indicators of Resilience | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Practices | Farm level biodiversity | Groundwater availability | Soil Erosion | Plant available nutrients | Infiltration of water into the soil | Soil microbial diversity | Soil aggregation | Soil water holding capacity |
| Boundary planting | ++ | +/- | ++ | + | + | ++ | ++ | + |
| Evergreen agriculture | ++ | +/- | ++ | ++ | ++ | ++ | ++ | ++ |
| Farmer managed natural regeneration | ++ | +/- | ++ | ++ | ++ | ++ | ++ | ++ |
| Multistrata | ++ | +/- | ++ | ++ | ++ | ++ | ++ | ++ |
| | Intercropping | | | | | | | |
| Rows/alleys (N-fixing) | ++ | +/- | ++ | ++ | ++ | ++ | ++ | ++ |
| Rows/alleys (non-N-fixing) | ++ | +/- | ++ | + | ++ | ++ | ++ | ++ |
| Mixed (N-fixing) | ++ | + | ++ | ++ | ++ | ++ | + | ++ |
| Mixed (non-N-fixing) | ++ | +/- | ++ | + | ++ | + | ++ | ++ |
| Home gardens | + | + | ++ | + | ++ | ++ | + | + |
| Live fences | ++ | +/- | ++ | + | + | ++ | + | + |
| Parklands | ++ | + | ++ | ++ | + | ++ | ++ | ++ |
| Silvopasture | ++ | +/- | + | + | ++ | ++ | + | ++ |
| Woodlots | ++ | +/- | + | + | ++ | ++ | ++ | ++ |

Table 3.5: Impacts of CSA practices on mitigation indicators in agroforestry systems.

| **Agroforestry Systems** | **Indicators of Mitigation** | | | | | |
|---|---|---|---|---|---|---|
| Practices | Changes in land use | Emissions from inputs | Carbon sequestered in soil | Carbon sequestered in biomass | N2O emissions | CH4 emissions |
| Boundary planting | + | + | + | + | + | +/- |
| Evergreen agriculture | + | + | ++ | ++ | + | +/- |
| Farmer managed natural regeneration | + | + | ++ | ++ | + | +/- |
| Multistrata | + | + | ++ | ++ | + | +/- |
| | Intercropping | | | | | |
| Rows/alleys (N-fixing) | +/- | +/- | ++ | + | -- | +/- |
| Rows/alleys (non-N-fixing) | + | + | ++ | + | + | +/- |
| Mixed (N-fixing) | +/- | +/- | ++ | ++ | -- | +/- |
| Mixed (non-N-fixing) | + | - | ++ | ++ | + | +/- |
| Home gardens | + | + | ++ | ++ | + | +/- |
| Live fences | + | + | + | + | + | +/- |
| Parklands | + | + | ++ | ++ | + | +/- |
| Silvopasture | +/- | +/- | ++ | ++ | +/- | +/- |
| Woodlots | + | + | ++ | ++ | + | +/- |

# Appendix 4: Livestock systems

Table 4.1: Climate risk mitigation in livestock systems.

| **Livestock** | **Addressing Climate Risks** | | | | |
|---|---|---|---|---|---|
| **Practices** | Increased growing season temperature | Intra-seasonal droughts | Shortening of growing seasons | Unpredictable seasons | Increased rainfall intensity |
| | Diet Management | | | | |
| Non-conventional feeds | + | + | + | + | +/- |
| Improved feed quality | +/- | + | +/- | +/- | +/- |
| Improved digestibility | +/- | + | +/- | +/- | +/- |
| Improved protein content | +/- | + | +/- | +/- | +/- |
| Improved supplements | + | + | +/- | + | +/- |
| | Improved Pastures | | | | |
| Planting N-fixing legumes | +/- | +/- | +/- | + | + |
| Fodder shrubs | +/- | + | +/- | + | + |
| | Rangeland Management | | | | |
| Rotational grazing | +/- | + | +/- | + | + |
| Cut-and-carry | +/- | + | + | + | +/- |
| | Manure Management | | | | |
| Manure collection | +/- | +/- | +/- | +/- | +/- |
| Improved manure storage | + | +/- | +/- | +/- | +/- |
| Manure treatment | + | +/- | +/- | +/- | +/- |
| Vaccines | + | + | +/- | +/- | +/- |
| Changing breeds | + | + | +/- | + | +/- |
| Artificial insemination | + | +/- | +/- | +/- | +/- |
| Wells (boreholes) | + | ++ | +/- | + | +/- |

Table 4.2: Constraints to adoption of CSA in livestock systems.

| **Livestock** | **Socioecological Factors** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Practices** | Access to finance | land tenure | Access to ext. services | Access to market info. | Labour avail. | Access to Transport. | Off-farm jobs |
| | Diet Management | | | | | | |
| Non-conventional feeds | + | +/- | + | + | +/- | + | +/- |
| Improved feed quality | + | + | + | + | + | + | +/- |
| Improved digestibility | + | + | + | + | + | + | +/- |
| Improved protein content | + | + | + | + | + | + | +/- |
| Improved supplements | + | + | + | + | +/- | + | +/- |
| | Improved Pastures | | | | | | |
| Planting N-fixing legumes | + | +/- | + | +/- | +/- | +/- | +/- |
| Fodder shrubs | + | +/- | +/- | +/- | +/- | +/- | +/- |
| | Rangeland Management | | | | | | |
| Rotational grazing | + | + | + | +/- | +/- | +/- | +/- |
| Cut-and-carry | + | +/- | + | +/- | + | +/- | +/- |
| | Manure Management | | | | | | |
| Manure collection | + | +/- | +/- | +/- | + | +/- | +/- |
| Improved manure storage | + | + | +/- | +/- | + | +/- | +/- |
| Manure treatment | + | + | + | +/- | + | +/- | +/- |
| Vaccines | + | +/- | +/- | + | +/- | +/- | +/- |
| Changing breeds | + | +/- | + | + | +/- | +/- | +/- |
| Artificial insemination | + | +/- | + | + | +/- | + | +/- |
| Wells (boreholes) | + | + | +/- | + | +/- | +/- | +/- |

Table 4.3: Impacts of CSA practices on select indicators of productivity in livestock systems.

| **Livestock** | **Indicators of Productivity** | | | | | |
|---|---|---|---|---|---|---|
| **Practices** | Animal growth | Variability | Labour | Income | Labor by women | Income of women |
| | Diet Management | | | | | |
| Non-conventional feeds | + | + | +/- | + | +/- | +/- |
| Improved feed quality | ++ | + | + | + | +/- | +/- |
| Improved digestibility | ++ | + | + | + | +/- | +/- |
| Improved protein content | ++ | + | +/- | + | +/- | +/- |
| Improved supplements | ++ | + | +/- | + | +/- | + |
| | Improved Pastures | | | | | |
| Planting N-fixing legumes | + | + | +/- | + | +/- | + |
| Fodder shrubs | + | + | - | + | +/- | + |
| | Rangeland Management | | | | | |
| Rotational grazing | + | + | - | + | - | + |
| Cut-and-carry | + | + | - | + | - | + |
| | Manure Management | | | | | |
| Manure collection | +/- | +/- | +/- | + | +/- | +/- |
| Improved manure storage | +/- | +/- | +/- | + | +/- | +/- |
| Manure treatment | +/- | +/- | +/- | + | +/- | +/- |
| Vaccines | + | + | +/- | + | +/- | + |
| Changing breeds | + | + | +/- | + | +/- | + |
| Artificial insemination | + | + | +/- | + | +/- | +/- |
| Wells (boreholes) | +/- | + | +/- | + | +/- | +/- |

Table 4.4: Impacts of CSA practices on select indicators of resilience in livestock systems.

| **Livestock** | **Indicators of Resilience** | | | | | |
|---|---|---|---|---|---|---|
| **Practices** | Farm level biodiversity | Groundwater availability | Soil Erosion | Available nutrients | Infiltration of water into the soil | Soil microbial diversity |
| | Diet Management | | | | | |
| Non-conventional feeds | + | +/- | +/- | + | +/- | + |
| Improved feed quality | +/- | +/- | +/- | + | +/- | +/- |
| Improved digestibility | +/- | +/- | +/- | + | +/- | +/- |
| Improved protein content | +/- | +/- | +/- | + | +/- | +/- |
| Improved supplements | +/- | +/- | +/- | + | +/- | +/- |
| | Improved Pastures | | | | | |
| Planting N-fixing legumes | + | +/- | +/- | + | + | + |
| Fodder shrubs | + | - | +/- | + | + | + |
| | Rangeland Management | | | | | |
| Rotational grazing | + | +/- | + | + | + | + |
| Cut-and-carry | +/- | +/- | +/- | + | +/- | + |
| | Manure Management | | | | | |
| Manure collection | +/- | +/- | +/- | + | +/- | +/- |
| Improved manure storage | +/- | +/- | +/- | + | +/- | +/- |
| Manure treatment | +/- | +/- | +/- | + | +/- | +/- |
| Vaccines | +/- | +/- | +/- | +/- | +/- | +/- |
| Changing breeds | +/- | +/- | +/- | +/- | +/- | +/- |
| Artificial insemination | +/- | +/- | +/- | +/- | +/- | +/- |
| Wells (boreholes) | +/- | +/- | +/- | +/- | +/- | +/- |

Table 4.5: Impacts of CSA practices on mitigation indicators in livestock systems.

| **Livestock** | **Indicators of Mitigation** | | | | | |
|---|---|---|---|---|---|---|
| **Practices** | Changes in land use | Emissions from inputs | Carbon sequestered in soil | Carbon sequestered in biomass | N2O emissions | CH4 emissions |
| | Diet Management | | | | | |
| Non-conventional feeds | + | +/- | +/- | +/- | +/- | + |
| Improved feed quality | +/- | +/- | + | + | +/- | + |
| Improved digestibility | + | +/- | +/- | + | +/- | + |
| Improved protein content | +/- | +/- | + | + | +/- | + |
| Improved supplements | +/- | +/- | +/- | +/- | +/- | + |
| | Improved Pastures | | | | | |
| Planting N-fixing legumes | +/- | +/- | + | +/- | +/- | +/- |
| Fodder shrubs | +/- | +/- | + | +/- | - | +/- |
| | Rangeland Management | | | | | |
| Rotational grazing | +/- | +/- | + | +/- | +/- | +/- |
| Cut-and-carry | +/- | +/- | +/- | +/- | +/- | +/- |
| | Manure Management | | | | | |
| Manure collection | +/- | +/- | +/- | +/- | +/- | +/- |
| Improved manure storage | +/- | +/- | +/- | +/- | +/- | +/- |
| Manure treatment | +/- | +/- | +/- | +/- | +/- | +/- |
| Vaccines | +/- | +/- | +/- | +/- | +/- | +/- |
| Changing breeds | +/- | +/- | +/- | +/- | +/- | +/- |
| Artificial insemination | +/- | +/- | +/- | +/- | +/- | +/- |
| Wells (boreholes) | +/- | +/- | +/- | +/- | +/- | +/- |

# Appendix 5: Aquaculture systems

Table 5.1: Climate risk mitigation in aquaculture systems.

| **Aquaculture** | **Addressing Climate Risks** | | | | |
|---|---|---|---|---|---|
| Practices | Increased growing season temperature | Intra-seasonal droughts | Shortening of growing seasons | Unpredictable seasons | Increased rainfall intensity |
| | Diet Management | | | | |
| Non-conventional feeds | + | + | + | + | +/- |
| Improved feed quality | + | + | + | + | +/- |
| Improved digestibility | + | + | + | + | +/- |
| Improved protein content | + | + | + | + | +/- |
| Improved supplements | + | + | + | + | +/- |

Table 5.2: Constraints to adoption of CSA in aquaculture systems.

| **Aquaculture** | **Socioecological Factors** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Practices | Access to finance | land tenure | Access to ext. services | Access to market info. | Labour avail. | Access to Transport. | Off-farm jobs | Access to irrigation |
| | Diet Management | | | | | | | |
| Non-conventional feeds | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved feed quality | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved digestibility | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved protein content | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved supplements | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** | **+/-** |

Table 5.3: Impacts of CSA practices on select indicators of productivity in aquaculture systems.

| **Aquaculture** | **Indicators of Productivity** | | | | | |
|---|---|---|---|---|---|---|
| Practices | Animal growth | Variability | Labour | Income | Labor by women | Income of women |
| | Diet Management | | | | | |
| Non-conventional feeds | ++ | ++ | + | + | + | + |
| Improved feed quality | ++ | ++ | + | + | + | + |
| Improved digestibility | ++ | ++ | + | + | + | + |
| Improved protein content | ++ | ++ | + | + | + | + |
| Improved supplements | ++ | ++ | + | + | + | + |

Table 5.4: Impacts of CSA practices on select indicators of resilience in aquaculture systems.

| **Aquaculture** | Indicators of **Resilience** | | |
|---|---|---|---|
| Practices | Farm level biodiversity | Groundwater availability | Available nutrients |
| | Diet Management | | |
| Non-conventional feeds | + | + | + |
| Improved feed quality | + | + | + |
| Improved digestibility | + | + | + |
| Improved protein content | + | + | + |
| Improved supplements | + | + | + |

Table 5.5: Impacts of CSA practices on mitigation indicators in aquaculture systems.

| **Aquaculture** | **Indicators of Mitigation** | | | |
|---|---|---|---|---|
| Practices | Changes in land use | Emissions from inputs | N2O emissions | CH4 emissions |
| | Diet Management | | | |
| Non-conventional feeds | **+/-** | **+/-** | **+/-** | **+** |
| Improved feed quality | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved digestibility | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved protein content | **+/-** | **+/-** | **+/-** | **+/-** |
| Improved supplements | **+/-** | **+/-** | **+/-** | **+/-** |

# Appendix 6: Select technical guides[2]

**Cereal-based systems**

Reduced tillage

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2. Conservation Farming Unit Unit (CFU) (2007) Conservation Farming & Conservation Agriculture Handbook for HOE Farmers in Agro-Ecological Regions I & IIa-Flat Culture. CF Handbook, Lusaka, Zambia. http://www.fsnnetwork.org/sites/default/files/conservation_agriculture__cf_handbook_for_hoe_farmers_zambia.pdf
3. Wekesa A and Jönsson M (2014) Sustainable Agriculture Land Management. We Effect and Vi Agroforestry. http://s3-eu-central-1.amazonaws.com/weeffect.org.wordpress.prod/wp-content/uploads/2017/12/14121225/We-Effect-SALM-Training-Manual_webb.pdf
4. Recha J, Kapukha M, Wekesa A, Shames S, and Heiner K (2014) Sustainable Agriculture Land Management Practices for Climate Change Mitigation: A training guide for smallholder farmers. Washington, DC. EcoAgriculture Partners. https://cgspace.cgiar.org/handle/10568/35643
5. FAO (2001) Guidelines and reference materials for promoting integrated soil and nutrient management in Farmer Field Schools. Reference material for the module on Tillage. Food and Agriculture Organization of the United Nations, Land and Plant Nutrition Management Service Land and Water Development Division. http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/tillage_module.pdf

No till

6. FAO (2001) Guidelines and reference materials for promoting integrated soil and nutrient management in Farmer Field Schools. Reference material for the module on Tillage. Food and Agriculture Organization of the United Nations, Land and Plant

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Nutrition Management Service Land and Water Development Division. http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/tillage_module.pdf

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8. FAO (2000) Manual on integrated soil management and conservation practices. Food and Agriculture Organization of the United Nations, Land and Plant Nutrition Management Service Land and Water Development Division and agricultural Engineering Branch of the agricultural support division. http://www.fao.org/family-farming/detail/en/c/329712/

Integrated soil Fertility Management

9. Fairhurst T (ed.) (2012) Handbook for Integrated Soil Fertility Management. Africa Soil Health Consortium, Nairobi. https://publications.cta.int/media/publications/downloads/1853_PDF.pdf
10. Fairhurst T (ed.) (2012) Handbook for Integrated Soil Fertility Management. Africa Soil Health Consortium, Nairobi. http://ssa.ipni.net/ipniweb/region/africa.nsf/0/F7501955BAE1F4F085257F080026F963/$FILE/ZARI.pdf
11. Sishekanu M, Mabengwa M, Makungwe M, Gondwe B, Banda F, Siulemba G, Kapulu N and Mutegi J (2015) Integrated Soil Fertility Management Training Manual for Zambia Agricultural Extension Workers. http://ssa.ipni.net/ipniweb/region/africa.nsf/0/F7501955BAE1F4F085257F080026F963/$FILE/ZARI.pdf
12. Sanginga N and Woomer PL (eds.) (2009) Integrated soil fertility management in Africa: principles, practices, and developmental process. Tropical Soil Biology and Fertility (TSBF) Institute of the International Center for Tropical Agriculture (CIAT). https://agrilinks.org/sites/default/files/resource/files/integrated_soil_fertility.pdf

Biochar

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Green manure

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18. FAO (2015) Training manual for organic agriculture. Climate, Energy and Tenure Division (NRC) and the Technologies and practices for smallholder farmers (TECA) Team from the Research and Extension Division (DDNR). FAO Headquarters in Rome, Italy. http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Compilation_techniques_organic_agriculture_rev.pdf
19. Weidmann G and Kilcher L (2011) African Organic Agriculture Training Manual. http://www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-02/Africa_Manual_M02.pdf

Compost

20. Edwards S and Araya H (2011) How to make and use compost. *Climate change and food systems resilience in Sub-Saharan Africa. Rome: FAO*, pp.379-476. http://www.fao.org/docrep/014/i2230e/i2230e14.pdf

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28. Zingore S, Njoroge S, Chikowo R, Kihara J, Nziguheba G and Nyamangara J (2014) 4R plant nutrient management in African agriculture: An extension handbook for fertilizer management in smallholder farming systems. http://ssa.ipni.net/ipniweb/region/africa.nsf/0/79A037DA41071A8043257D9A0054739B/$FILE/4R%20Extension%20Handbook.pdf

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31. International Institute of Rural Reconstruction (IIRR), African Conservation Tillage Network (ACT) (2005) Conservation agriculture: A manual for farmers and extension workers in Africa. http://www.fao.org/ag/ca/AfricaTrainingManualCD/PDF%20Files/04SOIL1.PDF

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Water harvesting

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Green manure

Using organic materials and manures


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Row/alleys (N-fixing)

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Rows/alleys (non-N-fixing)

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Live fences

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Parklands

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Silvopasture

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Woodlots

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**Livestock**

Non-conventional feeds

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Improved feed quality

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Improved digestibility

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Improved protein content

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Improved supplements

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Planting N-fixing legumes

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Fodder shrubs


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Rotational grazing

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# Appendix 7: Design principles for CSA in Africa

During the Pretoria workshop, NEPAD challenged participants to come up with simple principles for CSA in Africa. Participants defined four to frame 'CSA is in the African context'. CSA in Africa needs to (i) be farmer-centric, (ii) focus on productivity and resilience with mitigation as a co-benefit, (iii) prescribe to graduated changes in farming systems, and (iv) apply no-regret approaches (described below).

### Farmer-centric

Farmers and their needs and desires are at the core of what is CSA in Africa. Community and farmer participation drives the discussion and selection of practices and technologies. Most importantly, farmers should be given multiple options to choose from—taking advantage of their personal experience and preference to guide them in choosing the appropriate innovation.

### Productivity and resilience core

CSA efforts in Africa aim to increase productivity and resilience of farming activities. This dual emphasis is a direct response to the dominant need of the rural population of Africa. In many cases, improving the productivity and resilience will help mitigate climate change as well. However, farm activities are promoted based on their potential to address climate and social risks and needs, not on the basis of their mitigation potential. This approach is further evidenced based on the adoption of the metric of 'GHG intensity' (kg $CO_2$e per kg product) versus absolute emissions (kg $CO_2$eq) in the monitoring and evaluation framework for CSA in Africa.

### A process of graduated change

Climate-smart farming practices have particular characteristics that make them more or less suitable for various farmers and farming communities. These characteristics range from biophysical environment such as soil type to socioeconomic constraints such as land tenure. Even when the conditions are right, there is still often a process of stepwise change. When thinking about adoption of climate-smart agriculture, it is important to think of it as a dynamic process, where the first engagements are around socializing ideas about CSA and then followed with more accessible and adoptable farming activities (e.g., planting on time) that represent incremental changes in the farming system, which can later be followed with complex and perhaps transformative changes as dictated by climate and social risks and needs. This is implemented within this decision guide by identifying specific components of an agricultural system that can be modified with appropriate practices to become more "climate smart". Each year farmers can add additional CSA "components" to their agricultural systems—thus allowing for gradual change—e.g., becoming more climate-smart.

## No-regret approaches

Agricultural practices—CSA or otherwise—affect social, environmental and economic outcomes. The fact that changing an agricultural management practice can affect everything from soils to nutrition is one reason why agriculture is such a promising intervention for rural issues. The magnitude of the impacts that changing practices will have on various CSA-relevant outcomes is unknown in many cases, especially for the diverse range of potential outcomes of interest and the diversity of socio-ecological contexts. Regardless, there is sufficient information to move forward with CSA now; many CSA technologies and practices present 'no-regret' options. That is, they simply are just smart farming to best of our current knowledge. Despite uncertainty about the impacts across CSA outcomes, specific CSA practices can still be promoted especially where they have shown success and sustained adoption in the past.

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