Prioritizing Climate-Smart Agriculture Practices in Western Kenya

CIAT Working Paper
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This report on Prioritizing Climate-Smart Agriculture (CSA) Practices in Western Kenya has been prepared as an output for the CIAT-led, GIZ-funded project ‘Climate-smart soil protection and rehabilitation in Benin, Burkina Faso, Ethiopia, India, and Kenya,’ and has not been peer reviewed. Any opinions stated herein are those of the author(s) and do not necessarily reflect the policies or opinions of CIAT, donor agencies, or partners.

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<th>Description</th>
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<tr>
<td>CIAT</td>
<td>International Center for Tropical Agriculture</td>
</tr>
<tr>
<td>CO₂eq</td>
<td>carbon equivalent</td>
</tr>
<tr>
<td>CSA</td>
<td>climate-smart agriculture</td>
</tr>
<tr>
<td>ELMO</td>
<td>Evaluation of Land Management Options</td>
</tr>
<tr>
<td>FYM</td>
<td>farmyard manure</td>
</tr>
<tr>
<td>GHG</td>
<td>greenhouse gas</td>
</tr>
<tr>
<td>GIZ</td>
<td>Deutsche Gesellschaft für Internationale Zusammenarbeit</td>
</tr>
<tr>
<td>m.a.s.l.</td>
<td>meters above sea level</td>
</tr>
<tr>
<td>NGO</td>
<td>nongovernmental organization</td>
</tr>
<tr>
<td>SOC</td>
<td>soil organic carbon</td>
</tr>
<tr>
<td>SOM</td>
<td>soil organic matter</td>
</tr>
<tr>
<td>WOCAT</td>
<td>World Overview of Conservation Approaches and Technologies</td>
</tr>
</tbody>
</table>
Summary

A climate-smart agriculture (CSA) prioritization exercise in Western Kenya was carried out as part of the activities in the CIAT-led research project on ‘Climate-smart soil protection and rehabilitation in Western Kenya’, funded by GIZ. This project aims to encourage sustainable approaches to promote soil protection and rehabilitation of degraded soil in Benin, Burkina Faso, Ethiopia, India and Kenya. It also supports policy development for soil rehabilitation, soil information, and extension systems.

A two-day regional workshop with 45 participants was held in Western Kenya; participants were local agricultural experts, representatives of agriculture related local NGOs and farmers from Bungoma, Kakamega and Siaya counties. Six farmers were invited from each of the five farm typologies (that had previously been identified by this project): i) small-scale mixed subsistence; ii) medium-scale mixed with commercial horticulture; iii) medium-scale mixed with commercial dairy; iv) medium-scale mixed with commercial cereal; and v) large-scale commercial farming. Separate focus group discussions were held with farmers and local experts, respectively to explore the differences between stakeholders.

The workshop modules included: validation of the typologies in the three counties; CSA indicator selection; development of a short list of agricultural practices appropriate for each farm type; and climate-smartness assessment based on the three CSA pillars (i.e. production, adaptation and mitigation). Practices were prioritized using pairwise ranking and information on the potential benefits of practices by stakeholder was also documented.

This study highlights the value of evaluating which practices were preferred in a local context and highlights the climate smartness of these practices based on desired objectives by local experts and farmers. Efforts to increase soil restoration and rehabilitation in Western Kenya should target the prioritized practices in each farm type to achieve high adoption rates and attain CSA goals. In addition, barriers highlighted by the stakeholders should be considered. Assessing practices against the CSA pillars helps to ensure that prioritized practices can also provide win–win or co-benefits to climate change adaptation and mitigation.

Implementing this study was a way of testing the CSA prioritization framework developed by CIAT in 2014, which led to the development of a revised CSA prioritization process.

Key words
Climate-smart agriculture, climate smartness, indicators, prioritization.
1. Introduction

In developing countries, agriculture’s role in ensuring food security and in supporting development is a challenge in a changing climate. Climate-smart agriculture (CSA) aims to tackle three main objectives: sustainably increasing agricultural productivity and income; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas (GHG) emissions, where possible.

Usually, soil rehabilitation is evaluated for productivity and food security benefits, and little attention is paid to climate ‘smartness’. CSA initiatives in sub-Saharan Africa have previously focused less on soil protection and rehabilitation, despite their strong potential to influence climate smartness.

CIAT developed the CSA prioritization framework, which aims to guide stakeholders in optimizing national and subnational agricultural planning. The framework was implemented in Western Kenya with the aim of testing the methodology and refining it for wider use.

The specific objectives were to:
- Identify existing and promising CSA practices in relation to key farm types
- Develop a prioritized list of CSA practices and evaluate their climate smartness
- Understand the context-specific outcomes of these practices by different stakeholders
- Understand the costs and benefits of implementation and the opportunities and barriers in adopting prioritized practices.

Once developed, a portfolio of CSA practices can be used to channel agricultural investment funds in the face of climate change. The decision-making process by end users on what practice to implement or not is usually determined by their perceptions and desired outcomes, which vary across contexts. The prioritization of CSA technologies is a fundamental first step towards optimizing agricultural planning, minimizing trade-offs, and maximizing synergies.
2. Methodology

2.1 Study area

This study was conducted in three counties in Western Kenya (Siaya, Kakamega, and Bungoma). Siaya county is situated in the highlands of Western Kenya and covers an area of 2,496.1 km². The altitude of Siaya district ranges from 1,140 to 1,500 meters above sea level (m.a.s.l.). The county receives average rainfall of between 1,800 and 2,000 mm annually. The fertility of the soils in the county ranges from moderate to low, and levels of nitrogen and phosphorus are particularly low. The county is divided into six administrative sub-counties: Siaya, Bondo, Rarienda, Gem, Uguna and Ugenya. The main food crops include: maize, sorghum, millet, bean, cowpea, cassava, sweet potato, groundnut, and finger millet. Cash crops are: cotton, rice, sugarcane, and groundnuts. Livestock kept include cattle, goats, sheep, pigs, and poultry.

Kakamega county borders Vihiga county to the south, Busia county and Siaya county to the west and Bungoma to the north. The county covers an area of 3,033.8 km² and has a population size of 1,660,651, resulting in a population density of 547.38. The county has two rainy seasons with an average range of 1,300 to 2,200 mm annually. The temperatures range is between 18°C and 29°C while the altitude range is 1,240–2,000 m.a.s.l. Most farmers grow sugarcane, maize and tea as cash crops. Food crops include: maize, bean, cassava, finger millet, and sorghum. The average farm size is 3 ha and 10 ha for small-scale and large-scale farmers, respectively. The livestock bred in the county include cattle, sheep, goats, and pigs.

Bungoma county borders the Republic of Uganda to the northwest, Trans-Nzoia county to the northeast, Kakamega county to the east and southeast, and Busia county to the west and southwest. The annual rainfall in the county is 1,100 mm in a bimodal pattern. The main food crops include: maize, beans, finger millet, sweet potato, banana, Irish potato, and assorted vegetables. Sugarcane, cotton, palm oil, coffee, sunflower, and tobacco are grown as cash crops. The main livestock breeds in the county include: cattle, sheep, goats, donkeys, and pigs.

Generally, farming systems in Western Kenya are under pressure from the increasing population while the economic returns from farming are declining because of climate change and deteriorating levels of soil fertility. Farming systems are diversified and range from subsistence smallholdings to more cash-crop oriented farms, and different types of crop livestock systems. Nitisols, ferralsols, and acrisols are the main soil types in the region.
2.2 Validation of Western Kenya farm typologies

The five farm typologies developed by CIAT for Western Kenya were presented; participants were asked if they agreed with the farm typologies, and if they would like to add any more characteristics or changes. The main output of this exercise was to agree with the stakeholders on the scope of the project in relation to the main production systems.

2.3 Develop a long list of agricultural practices for the local context

Participants reviewed, discussed, and briefly described a long list of agricultural practices (e.g. soil, crop, livestock, and water management) that apply to the area of interest and that are linked to the production systems and sociological contexts, including those practices relevant for the site that are being promoted by partners in the region (e.g. government, NGOs, and development partners). They also discussed indicators for assessing the CSA practices. The main output was a long list of 20 to 30 practices.

2.4 Identify practices applicable to the five farm typologies

This stage involved stakeholders reviewing and prioritizing the long list of agricultural practices. Participants were divided according to the five farm typologies, with the farmers group kept separate from the local experts group. Each group was provided with the long list of practices generated and was asked to select only those practices that were relevant/useful to their farm type.

The discussion included the following questions:

i. To which production system/crop or livestock does this practice apply?

ii. What opportunities and benefits (i.e. economic, social and environmental) would you get if the practice was implemented?

iii. What are the barriers and challenges to implementation?

iv. What do you usually consider when you are deciding if you can use each practice? (for each practice). Identify the indicators for adoption/use.

2.5 Ranking/prioritization of the practices by pairwise ranking (for farm type)

i. For the selected practices, construct a pairwise matrix (i.e. each box in the matrix represents the intersection [or pairing] of two practices).

ii. Rank each pair. For each pair, the group (using a consensus-oriented discussion) should determine which of the two practices it prefers. Then, for each pair, it should write the name of the preferable practice in the appropriate box. Repeat this process until the matrix is complete.

iii. Note the reasons for the preference for each pair of practices.

iv. Count the number of times each practice appears in the matrix. Rank all practices. Rank the practices by the total number of times they appear in the matrix. To break a tie (i.e. where two practices appear the same number of times), look at the box in which those two practices are compared. The practice appearing in that box receives the higher ranking.

v. Present results from the pairwise ranking matrix exercise to each group.

vi. Ask the group to list the reasons for prioritizing the top five ranked practices.

2.6 Practice smartness assessment (individual work, with separate activities for farmers and expert groups)

• Each participant was asked to select three practices that they prefer or consider to be the most important in their farm or region.

• On the matrix provided (Appendix 1), assess the smartness of this practice for each of the indicators (and do not score for indicators you are unfamiliar with).
3. Results and discussion

3.1 Validation of Western Kenya typologies

Five farm typologies and characteristics listed under each had been generated from a previous CIAT-led workshop. During this workshop, participants included additional characteristics that they wish included for the typologies.

1. Small-scale mixed subsistence
   - Farmers in this category own 0.4 to 0.8 hectares of land and practice both dairy and crop production.
   - Maize and beans are the main crops cultivated.
   - Farmers in this category are resource poor.
   - This system is characterized by low yields and low soil fertility.
   - Livestock kept in this system is mainly local breeds.
   - It is a low risk strategy as farmers grow a high variety of crops.

   Additional characteristics suggested:
   - Tree planting is practiced on a small scale.
   - Aquaculture and rabbit keeping also on a small scale.

2. Medium-scale mixed with commercial horticulture
   - 1–3 hectares of land with both dairy and crop production but specializing in horticulture production mostly for sale.
   - The farms in this category are intensive and youths are most attracted.
   - This category requires knowledge and management skills.
   - This is a high-risk investment since horticultural crops are vulnerable to pests, diseases and bad weather.
   - Farmers in this category have embraced innovation technologies such as irrigation and green houses.
   - Farmers keep records and have access to credit facilities.

   Additional characteristics suggested:
   - Tree planting and rabbit keeping is also practiced.
3. Medium-scale mixed with commercial dairy

- 1–3 hectares with both livestock and crop production but specializing in dairy production mostly for sale.
- Their dairy cows consist of both local and exotic breeds.
- This system is characterized by high-quality feeds, zero grazing, artificial insemination, and potential for milk value chain.
- Farmers in this system have embraced new technologies such as biogas, hay, and silage production.

Additional characteristics suggested:
- Tree planting and rabbit keeping is also practiced.

4. Medium-scale mixed with commercial cereal

- 1–3 hectares of land with livestock and crop production but specializes in cereal production mostly for sale.
- Maize is the main crop, though other crops grown include beans, bananas and pumpkins.
- Animals kept are mainly local zebu, goat, and local poultry.
- This system requires large amounts of labor for cropping activities.

Additional characteristics suggested:
- Grow fodder crops such as Mulato and Brachiaria.
- Keeping rabbits and pigs.

5. Large-scale commercial

- More than 4 hectares of land, highly commercialized growing mostly sugarcane, maize, coffee, and rice.
- Crop production is mostly mechanized.
- More productive assets and adoption of innovative technologies.
- Reliance on hired or permanent labor.

Additional characteristics suggested:
- Participants believed this typology should include activities such as dog farming, pig farming, rabbit keeping.

3.2 Long list of agricultural practices in Western Kenya

The following 20 practices were listed as being implemented in Western Kenya. Several important messages can be derived. First, practices are related to agronomy (95%), and only 5% can be categorized as relating forestry and livestock management. Practices related to post-harvest management and food energy systems were not listed by participants. Second, practices were implemented mainly at the farm as compared to off-farm or programmatic level. On-farm refers to practices that farmers could implement directly on their plot(s) without exceeding the farm boundaries. Practice implementation depends on individual effort. Off-farm practice implementation depended on individual/collective efforts and required exceeding the boundaries of a farm/community e.g. conservation of water resources, community seed banks, etc. Programmatic practice was developed and implemented through collective efforts at the landscape level. It involved institutional support for development and maintenance. Programmatic practices acted as enablers of other practices e.g. early warning systems, extension services.

1. Water harvesting
2. Intercropping
3. Crop rotation
4. Terracing
5. Mulching
6. Minimum tillage
7. Incorporate residue
8. Composting
9. Agroforestry
10. Liming
11. Push and pull
12. Fallowing
13. Dry planting  
14. Certified seed  
15. Grass strips e.g. vetiver grass  
16. Organic manure  
17. Cover crop  
18. Conservation agriculture  
19. Use of herbicides  
20. Organic manure

3.3 CSA pillar assessment

During the workshop, the stakeholders discussed the weighting to be assigned to each of the three different CSA pillars (productivity, adaptation, and mitigation) according to the estimated changes or objectives they would like to see in the future. Figure 1 reveals the current and long-term interest that the stakeholders had with regard to CSA investment. Stakeholders noted that climate change is still a new phenomenon and the communities were largely unaware of adaptation and mitigation options. For Western Kenya, stakeholders were more interested in investing in practices related to increases in agricultural productivity. However, with the threat of climate change, the long-term interest was towards enhancing adaptation (from 20% to 40%) and mitigation (from 5% to 10%).

![Figure 1: Current and long-term desired objectives between the three CSA pillars by stakeholders in Western Kenya](image)

3.4 CSA indicator selection

For every CSA pillar, the experts selected a list of potential indicators, which were then used for assessing the practices' impacts on CSA pillars. Table 1 shows a list of indicators proposed, based on relevance to the context, information availability, and quality.
Selecting the indicators helps to guide the assessment of practices’ impacts on the three CSA pillars and allowed for later ranking of the practices according to their aggregate impact on the CSA pillars. The indicator analysis also provides the base of discussions on the trade-offs between achievement of the three goals of CSA, desired outcomes of stakeholders, and barriers to adoption.

### 3.5 Prioritizing practices for each farm type (short list)

Farmers were grouped separately by each farm type and each selected the most important practices from the long list of agricultural practices arrived at in the previous exercise. Then they ranked the selected practices in order of importance using a pairwise matrix comparison. The selection of these practices involved indicating the farm types in which they were practiced, the main benefits, barriers/challenges of implementation, and the important things they considered while selecting the practice for their farm types.

The short list of practices (Table 2) represents practices adapted to a specific context (in this case farm type) and could be game changers for the agricultural sector in the face of climate change.
Table 2: Pairwise ranking of practices for each farm type

<table>
<thead>
<tr>
<th>Small-scale mixed subsistence</th>
<th>Medium-scale mixed with commercial horticulture</th>
<th>Medium-scale mixed with commercial dairy</th>
<th>Medium-scale mixed with commercial cereal</th>
<th>Large-scale commercial</th>
</tr>
</thead>
</table>

We asked for the reasons why some practices were not being practiced although many farmers were aware of the practices. Some of the reasons stated were: small herd sizes (resulting in inadequate quantities of manure); lack of knowledge/skills to implement the practices; unavailability/high cost of inputs such as seed and lime; the perception that some practices do not show immediate benefit e.g. manure releases nutrients slowly compared to inorganic fertilizer. Farmers also mentioned small land size as a barrier to implementation of agroforestry, crop rotation and fallowing, especially in the small-scale mixed subsistence farm type. There are different practices short listed across the farm types, which indicates consideration of both biophysical and socioeconomic contexts in prioritizing practices.

3.5.1 Climate smartness assessment

In this step, local experts assessed the impacts of up to three practices selected in Activity 3.5 (short list), for each farm type, on the CSA pillars indicators from Activity 3.4. Qualitative assessment criteria were based on evaluating the practice’s potential impact on the indicator, where

-10 = Very high negative change  
(or 100% negative change)

-1 = Very low negative change  
(or 10% negative change)

0 = No change

1 = Very low positive change  
(or 10% positive change)

10 = Very high positive change  
(or 100% positive change)

N/A = Not applicable
### Figure 2: Assessment of prioritized practices in Western Kenya against the CSA pillars

<table>
<thead>
<tr>
<th>Farm type</th>
<th>Practice</th>
<th>Productivity</th>
<th>Adaptation</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small-scale mixed</td>
<td>Farmyard manure</td>
<td>5</td>
<td>23</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Conservation agriculture</td>
<td>5.2</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Composting</td>
<td>4.7</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Medium mixed-hort</td>
<td>Intercropping</td>
<td>3.6</td>
<td>3.5</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Certified seed</td>
<td>6.8</td>
<td>6.8</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Crop rotation</td>
<td>3.5</td>
<td>3.5</td>
<td>11</td>
</tr>
<tr>
<td>Medium mixed-dairy</td>
<td>Farmyard manure</td>
<td>3.8</td>
<td>3.8</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Agroforestry</td>
<td>4.5</td>
<td>4.5</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Inorganic fertilizer</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Medium mixed-cereal</td>
<td>Crop rotation</td>
<td>6.5</td>
<td>6.5</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Herbicide</td>
<td>6</td>
<td>6</td>
<td>-0.3</td>
</tr>
<tr>
<td></td>
<td>Inorganic fertilizer</td>
<td>7</td>
<td>7</td>
<td>4.5</td>
</tr>
<tr>
<td>Large-scale commercial</td>
<td>Conservation agriculture</td>
<td>5.6</td>
<td>5.6</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Liming</td>
<td>2.5</td>
<td>2.5</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Agroforestry</td>
<td>5.6</td>
<td>5.6</td>
<td>27</td>
</tr>
</tbody>
</table>

*Photo: Neil Palmer (CIAT)*
### Farm type | Practice | Productivity | Adaptation | Mitigation
--- | --- | --- | --- | ---
Small-scale mixed | Farmyard manure | 3.8 | 0.5 | 0.0
| Conservation agriculture | 3.9 | 0.5 | 0.1
| Composting | 3.6 | 0.5 | 0.1

Medium mixed-hort | Intercropping | 2.6 | 0.3 | 0.1
| Certified seed | 5.1 | 0.6 | N/A
| Crop rotation | 2.6 | 0.4 | 0.1

Medium mixed-dairy | Farmyard manure | 2.9 | 0.7 | 0.1
| Agroforestry | 3.4 | 0.5 | 0.1
| Inorganic fertilizer | 2.6 | 0.3 | -0.2

Medium mixed-cereal | Crop rotation | 4.9 | 0.1 | N/A
| Herbicide | 3.8 | 0.4 | 0.0
| Inorganic fertilizer | 5.2 | 0.2 | -0.2

Large-scale commercial | Conservation agriculture | 4.1 | 0.7 | 0.1
| Liming | 1.9 | 0.1 | N/A
| Agroforestry | 4.1 | 0.7 | 0.1

### Figure 3: Assessment of prioritized practices in Western Kenya against the CSA pillars showing indicators weighted value

Figures 4 and 5 show results from the assessment of the selected practices potential, for each farm type, against indicators related to the CSA pillars (productivity, adaptation, and mitigation). Figure 4 presents the average scores obtained from assessment of each practice potential impact on the CSA indicator. In Figure 5, scores (in Figure 4) weighted based on the current percentage value of each CSA pillar (in Figure 1). Inorganic fertilizer, certified seed, and crop rotation had the highest productivity potential. Farmyard manure (FYM), conservation agriculture, and agroforestry had the greatest positive impact on adaptation. For mitigation potential, agroforestry, composting, and conservation agriculture had the greatest potential for positive contribution, whereas inorganic fertilizer and use of herbicides had negative impacts.

The agroforestry system considered in this evaluation was use of dual-purpose tree species that provide timber, fodder, and fruits. Conservation agriculture (CA) contributes to mitigation through avoiding soil compaction, reducing water run-off, increasing aeration of the soils, and increasing the soil carbon.

For mitigation potential, the ability to increase the carbon input (below and above ground biomass), as well as reduce the quantity of greenhouse gases (GHG) released per season was considered. GHG refers to carbon dioxide equivalent (CO₂eq). Compost, crop residue (as part of conservation agriculture), and FYM could contribute to soil carbon sequestration, and thus to mitigation. Compost and FYM also have an indirect contribution to mitigation by substituting for the use of on-farm inorganic fertilizers. Fertilizers generate GHG...
Biomass accumulation can be enhanced using crop rotation and intercropping systems. Biomass return to the soil can be improved by maintaining a dense vegetation cover on the soil surface, which can also prevent soil from erosion for soil organic carbon (SOC) loss such as through agroforestry and fallowing.

Intercropping has many benefits. It suppresses weeds and insects, controls plant disease, resists climate extremes, and increases overall productivity with limited resources. The classic example of mixed cropping in Western Kenya is maize, bean, and soybean.

<table>
<thead>
<tr>
<th>Farm typology</th>
<th>CSA practice</th>
<th>Productivity</th>
<th>Adaptation</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small-scale mixed subsistence farming</td>
<td>Composting</td>
<td>Improves yields.</td>
<td>Increase soil fertility and productivity. Promotes soil conservation, reduces soil salinity and improves water retention.</td>
<td>Reduces methane emissions and can lead to a reduction in the inorganic fertilizers required.</td>
</tr>
<tr>
<td></td>
<td>Use of FYM</td>
<td>Improves yields and income.</td>
<td>Increase soil fertility and productivity. Promotes soil conservation, reduces soil salinity and improves water retention.</td>
<td>Reduces methane emissions and can lead to a reduction in the inorganic fertilizers required.</td>
</tr>
<tr>
<td>Medium-scale mixed with commercial horticulture</td>
<td>Intercropping</td>
<td>Acts as a security against total crop failure and increases yields.</td>
<td>Add fertility to soil and helps in soil water retention.</td>
<td>Nitrogen fixation from leguminous crops reduces reliance on nitrogenous fertilizers.</td>
</tr>
<tr>
<td></td>
<td>Soil and water harvesting</td>
<td>Improves yields and income.</td>
<td>Promotes soil conservation, improves water retention and reduces water use.</td>
<td>Reduces emission of N₂O.</td>
</tr>
<tr>
<td></td>
<td>Use of certified seed</td>
<td>Improves yields and income.</td>
<td>Increase productivity of land per unit area.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Inorganic fertilizer</td>
<td>Improves yields and income.</td>
<td>Increase productivity of land per unit area.</td>
<td>Recommended rates do not emit GHGs above dangerous levels.</td>
</tr>
<tr>
<td></td>
<td>Crop rotation</td>
<td>Improves yields and income.</td>
<td>Controls pests and diseases.</td>
<td>Maintains soil carbon stocks and soil organic matter content.</td>
</tr>
</tbody>
</table>

Table 3: Detailed assessment of contribution of prioritized practices to CSA pillars by local experts in Western Kenya

Crop rotation can improve biomass production and soil carbon sequestration, especially rotations with nitrogen-fixing legumes that can substantially reduce the nitrogen input by chemical fertilizers. Increasing cropping intensity or cropping more frequently by reducing the frequency of bare land in the crop rotation and intercrop is another effective approach to improving biomass production and soil C sequestration, as well as returning more crop residues to the soil compared to a monoculture.
<table>
<thead>
<tr>
<th>Farm typology</th>
<th>CSA Practice</th>
<th>Productivity</th>
<th>Adaptation</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-scale mixed with commercial cereal</td>
<td>Agroforestry</td>
<td>Increased and diversification of sources of income.</td>
<td>Increase soil fertility, acts as a windbreaker and controls soil erosion.</td>
<td>Carbon sequestration by trees and preserving and expanding carbon stocks.</td>
</tr>
<tr>
<td></td>
<td>FYM</td>
<td>Improves yields and income.</td>
<td>Increase soil fertility and productivity. Promotes soil conservation, reduces soil salinity and improves water retention.</td>
<td>Reduces methane emissions and can lead to a reduction in the inorganic fertilizers required.</td>
</tr>
<tr>
<td></td>
<td>Inorganic fertilizer</td>
<td>Improves yields and income.</td>
<td>Increase productivity of land per unit area.</td>
<td>Recommended rates do not emit GHGs above dangerous levels.</td>
</tr>
<tr>
<td></td>
<td>Manure application</td>
<td>Improves yields and income.</td>
<td>Increase soil fertility and productivity. Promotes soil conservation, reduces soil salinity and improves water retention.</td>
<td>Reduces methane emissions and can lead to a reduction in the inorganic fertilizers required.</td>
</tr>
<tr>
<td>Medium-scale mixed with commercial cereal</td>
<td>Herbicide</td>
<td>Improves yields and income.</td>
<td>Increases productivity per unit area of land.</td>
<td>Recommended rates do not emit GHGs above dangerous levels.</td>
</tr>
<tr>
<td></td>
<td>Fertilizer application</td>
<td>Improves yields and income.</td>
<td>Increase productivity of land per unit area.</td>
<td>Recommended rates do not emit GHGs above dangerous levels.</td>
</tr>
<tr>
<td></td>
<td>Post-harvest handling</td>
<td>Improves quality of products and income.</td>
<td>Reduces post-harvest losses thus increasing food security.</td>
<td>Reduces GHG emissions.</td>
</tr>
<tr>
<td>Large-scale commercial farming system</td>
<td>CA</td>
<td>Improved yields and income.</td>
<td>Maintains soil structure and increases soil fertility.</td>
<td>Facilitates carbon sink in soils. Reduces nitrogen loss.</td>
</tr>
<tr>
<td></td>
<td>Agroforestry</td>
<td>Increased and diversification of sources of income.</td>
<td>Increase soil fertility, acts as a windbreaker and controls soil erosion.</td>
<td>Carbon sequestration by trees and preserving and expanding carbon stocks.</td>
</tr>
<tr>
<td></td>
<td>Liming</td>
<td>Improved yields and income.</td>
<td>Regulates soil PH and improves soil fertility.</td>
<td>Stops or reverses the accumulation of CO₂ in the atmosphere.</td>
</tr>
<tr>
<td></td>
<td>Use of certified seeds</td>
<td>Improves yields and income.</td>
<td>Increase productivity of land per unit area and uniform germination.</td>
<td>-</td>
</tr>
</tbody>
</table>

### 3.5.2 Benefits and barriers for the top five prioritized practices

After listing the top three technologies per farm type, both from experts and farmers, we narrowed the list down to five practices (agroforestry, inorganic fertilizer, intercropping, improved seeds and liming) that were listed as the best across all farm typologies by both farmers and experts.
1. Agroforestry

**Benefits**
- Agroforestry helps in the production of timber and fuel, thus providing an alternative means of renewable energy.
- It leads to the production of animal feeds i.e. some of the trees can act as livestock feeds.
- It helps in conserving soil and improving soil quality.
- It results in diversification of income through simultaneous cultivation of valuable trees and crops.
- It provides a suitable microclimate that increases crop yields which in turn increases farm income. It also provides shelter for livestock.
- It sequesters atmospheric carbon thus providing mitigation benefits.
- Animals and intercrops are protected by the trees that shield them from the wind, offer shelter from the rain, wind and sun, keep the soil in place and stimulate soil microflora and fauna (i.e. encourage biodiversity)
- The deep tree roots recover drained or leached nutrients; the soil is enriched with tree litter and the dead roots of the trees.

**Barriers**
- Difficulty in accessing the seeds.
- A culture that hinders agroforestry practice.
- Negative attitude to agroforestry.
- Lack of knowledge about the type of trees to use. Agroforestry requires knowledge of technology (e.g. methods of combining different plants, their compatibility and effects on each other). Agroforestry technologies can fail when applied to the wrong situation.
- Land tenure system that discourages tree planting.
- Produces canopy reducing crop productivity.
- De-stamping is laborious and expensive.
- Trees and shrubs may take a long time to mature thus delaying income.

2. Inorganic fertilizer

**Benefits**
- It improves soil fertility
- It aids faster release of nutrients, i.e. nutrients are immediately available to plants.
- It is easier to transport than organic fertilizers.
- It leads to an increase in animal and crop production.
- The exact amounts of a given element can be calculated and given to plants.

**Barriers**
- They cost more than organic fertilizers.
- Their continuous use can alter soil pH.
- Commercial fertilizer, especially nitrogen, is easily washed below the level of the plant’s root system through the leaching of rain or irrigation.
- An application which is too heavy or too close to the roots of the plants may cause “burning” i.e. a process of desiccation by the chemical salts in the fertilizer.
- They contain certain compounds and salts which may alter soil chemistry in the long run.
3. Intercropping

**Benefits**
- It enables efficient utilization of available resources (nutrients and water).
- It leads to increased and diversified farm production and income.
- When leguminous crops are involved, intercropping enhances atmospheric nitrogen transfer and transfer of nitrogen to the main crop.
- It reduces soil erosion.
- It promotes ecological diversity e.g. increasing population of soil microorganisms that would be not available in a single crop system.
- It helps to control weeds by having crops cover most of the available land.
- It minimizes the incidence of pests and diseases.
- It acts as an insurance against total crop failure and reduces reliance on one crop with the normal challenge of agricultural products price fluctuations.
- It can modify the microclimate by reducing light intensity, air temperature, desiccating wind, and other climatic components which may increase the yield of the main crop.

**Barriers**
- A higher volume of fertilizer or irrigation water cannot be utilized as the component crops vary in their response to these resources.
- Yields for the main crop may reduce if the other crop has a higher competitive ability for taking up nutrients and water or if poor crop combinations are used.
- Management of intercrops using different cultural practices can be a difficult task e.g. weeding which may be done by hand.
- Harvesting is difficult especially when some crops mature faster than others.
- Where labor is scarce and expensive, intercropping can increase the cost of production.

4. Use of improved seeds

**Benefits**
- It leads to increased production of yields making farmers climate resilient.
- It promotes a higher germination percentage.
- It enhances uniform germination.
- In some crops, improved seeds aid improved nutrition.
- It helps to ensure the maximum use of available inputs.
- Some improved seeds are disease and climate tolerant.

**Barriers**
- Purchasing the seeds is expensive.
- There is lack of technical know-how.
- Accessibility to and availability of the right seeds can be difficult.
- Yield increase is associated with fertilizer type and nutrient levels.
- There can be heavy post-harvest loss of some varieties if it is not properly handled.

5. Liming

**Benefits**
- It leads to an increase in the production of yields.
- It buffers soil acidity.
- The cost of labor is reduced.
- It increases soil microbial activity.
- It improves soil structure i.e. the physical condition.
- It reduces the toxicity of Mn$^{2+}$ and Al$^{3+}$ cations.
- It increases the availability of Ca$^{2+}$ and Mg$^{2+}$ that are unavailable at a lower soil pH.

**Barriers**
- Lack of technical know-how
- Limited access to lime testing services
- Soil testing is required before adding lime, which takes time and is costly.
- If soils are too alkaline, nutrients such as iron, manganese, zinc and phosphorus become inaccessible to crops.
- Its effect is not effective.
3.5.3 Assessment of prioritized practices against farmers preferred indicators

Farmers were not aware of CSA and, therefore, had a different set of indicators, which they used to select agricultural practices. In Western Kenya, the most important indicators were: yield, reduced yield variability, income, soil erosion, soil organic matter (SOM) and amount of water available for production. Such indicators were important because they helped to identify not only the barriers to the uptake of the prioritized practices but also the trade-offs that adoption might bring.

Farmers in each farm type then ranked how each prioritized practice was expected to contribute to these indicators.

A. Small-scale mixed subsistence

In the small-scale subsistence farm type, farmers considered yield and income as the most desired benefits. Results in Figure 4 show that FYM was preferred most followed by crop rotation, intercropping, and residue management and mulching. Farms in this category are characterized by low soil fertility and low resource endowment, therefore the consideration of resources available within the farm such as manure and crop residue is valuable. There could be a challenge in obtaining adequate amounts of manure due to the small number of livestock and poultry that are kept in most farms. A major portion of the crop residues harvested on a farm is used as feed for livestock, presenting a tradeoff in recycling back to crop fields as manure.

Figure 4: Assessment of practices against farmer indicators in small-scale mixed subsistence farm type
B. Medium-scale mixed with commercial horticulture

In the medium-scale mixed with commercial horticulture farm type, intercropping and the use of certified seeds were reported by farmers as the greatest contributors to yield and income. Intercropping reduced yield variability in a season and improved the SOM content. Agroforestry and intercropping were seen as useful for increasing amount of water available in the soil. For soil erosion, both agroforestry and intercropping were rated as having medium benefits (Figure 5).

![Figure 5: Assessment of practices against farmer indicators in medium-scale with commercial horticulture farm type](image)

C. Medium-scale mixed with commercial dairy

In the medium-scale mixed with commercial dairy farm type, the use of FYM and certified seeds were rated as the best options for increasing yield and income and reducing yield variability in one season. FYM was preferred for improving SOM, terracing was preferred for controlling erosion, while the use of FYM, terracing and crop rotation had some benefits in terms of increasing water availability in the soil (Figure 6).
D. Medium-scale mixed with commercial cereal

In the medium-scale mixed with commercial cereal farm type, among the prioritized practices, the use of certified seeds is most beneficial for improving yield and income and reducing yield variability. Composting and agroforestry are rated as high for improving SOM while terracing is beneficial for controlling erosion (Figure 7).
E. Large-scale commercial farming system

In a large-scale commercial farming system, early planting is preferred for increasing yield, income, and reducing yield variability. Terracing is better for controlling soil erosion and soil liming will produce small benefits in terms of yield and SOM (Figure 8).

Figure 8: Assessment of practices against farmer indicators in large-scale commercial farm type
4. Conclusions and recommendations

This study highlights the value of evaluating the practices that are preferred in a local context and highlights any differences in preference according to farm types as well as desired objectives between local experts (such as contribution to climate smartness) and farmers (farmer preferred indicators). This highlights the importance of local context prioritization based on both biophysical and socioeconomic criteria. CSA is context specific and the degree of focus on a specific strategy and the CSA pillar stakeholders were interested in investing in would depend on the levels of economic development, agroecological conditions, and social setting.

Efforts to increase soil restoration and rehabilitation in Western Kenya could target the prioritized practices in each farm type as a way of ensuring high adoption rates. In addition, assessing the practices against the CSA pillars will ensure that prioritized practices can provide win-win or co-benefits, and existing trade-offs can be identified. This will promote practices that will have a positive impact on climate change (i.e. adapt and reduce or minimize GHG emissions). In addition, it is important to consider practices that contribute to a wide range of desired outcomes for the communities as this also ensures ownership and sustainability. Barriers highlighted by the stakeholders to implementing the practices must also be addressed. The study also highlighted gaps in awareness among farmers on a wide range of practices including livestock and energy saving technologies which could also play an indirect beneficial role in improving soils in Western Kenya. For example, energy-saving technologies have the potential of reducing the dependence on trees for firewood, aiding in promoting agroforestry. Practices that have been proved to be successful elsewhere, in similar contexts should be explored and evaluated with stakeholders for possible implementation.

This study aimed to further test the CSA prioritization process developed by CIAT and to refine it for wider implementation. The CSA prioritization framework was developed to help stakeholders generate a portfolio of CSA practices that could be used for channeling agricultural investment funds in the face of climate change. The process is flexible and can be adapted to the needs of various stakeholder groups including national governments, NGOs, regional decision-making bodies, development organizations, community-based organizations and donors. The structure of the framework focuses on the farm level as a first step in achieving CSA food systems in the long term. The Western Kenya project led to the refinement and development of a revised prioritization process (presented as a separate output of the project, and not shown here). The new process integrates worldwide sourcing of a wide range of potential practices from databases such as the World Overview of Conservation Approaches and Technologies (WOCAT) and a detailed evaluation of barriers and benefits of management options (e.g. using the Evaluation of Land Management Options (ELMO) tool developed by CIAT).
Appendix 1: Smartness assessment (individual work)

1. Name of production system (PS) analyzed:

2. Name of farm typology analyzed:

3. Name of practice analyzed:

4. Please provide quantitative and qualitative information on how each of the indicators below would impact 1 hectare of the production system selected in a season, in a scenario where the practice is IMPLEMENTED. Please use the -10 to 10 scale (as shown below), N/A for not applicable and N/D for no data.

<table>
<thead>
<tr>
<th>Indicator (Average)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yield of production system</td>
<td></td>
</tr>
<tr>
<td>2. Post-harvest loss in production system</td>
<td></td>
</tr>
<tr>
<td>3. Income generated from production system</td>
<td></td>
</tr>
<tr>
<td>4. Quantity of water available for production system</td>
<td></td>
</tr>
<tr>
<td>5. Quantity of water used per unit of product (water use efficiency)</td>
<td></td>
</tr>
<tr>
<td>6. Quality of water used for production</td>
<td></td>
</tr>
<tr>
<td>7. Soil capacity to retain water in areas under production</td>
<td></td>
</tr>
<tr>
<td>8. Level of soil disturbance (ploughing) for production</td>
<td></td>
</tr>
<tr>
<td>9. Ability of farmers to manage climate risks</td>
<td></td>
</tr>
<tr>
<td>10. Ability of farmers to limit the production system exposure to climate risks</td>
<td></td>
</tr>
<tr>
<td>11. Diversification of income sources on the farm</td>
<td></td>
</tr>
<tr>
<td>12. Use of local and traditional knowledge to manage production system</td>
<td></td>
</tr>
<tr>
<td>13. Quantity of above-ground biomass (ABG) available for production system</td>
<td></td>
</tr>
<tr>
<td>14. Quantity of below-ground biomass (BGB) available for production system</td>
<td></td>
</tr>
<tr>
<td>15. Content of soil organic matter (SOM) in soils accumulated in production system areas</td>
<td></td>
</tr>
<tr>
<td>16. Quality of animal diet (including diet diversification, forage quality) (Only for livestock production systems)</td>
<td></td>
</tr>
<tr>
<td>17. Quantity of manure produced that is left on pastures/fields (Only for livestock production systems)</td>
<td></td>
</tr>
<tr>
<td>18. Quantity of organic AND/OR inorganic fertilizer used per unit of product (mention type of fertilizer assessed: organic, inorganic or both) (Only for livestock)</td>
<td></td>
</tr>
<tr>
<td>19. Dietary energy supply (Amount of calorie available from production system)</td>
<td></td>
</tr>
<tr>
<td>20. Household income spent on food (per month or per season, please specify)</td>
<td></td>
</tr>
<tr>
<td>21. Amount of soil lost through erosion</td>
<td></td>
</tr>
<tr>
<td>22. Quantity of greenhouse gases (GHG) released per unit of product (PS) per season. GHG refers to carbon dioxide equivalent (CO$_2$eq)</td>
<td></td>
</tr>
</tbody>
</table>
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