Performance and Potential of Conservation Agriculture for Climate Change Adaptation and Mitigation in Sub-Saharan Africa

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An assessment of WWF and CARE projects in support of the WWF-CARE Alliance's Rural Futures Initiative

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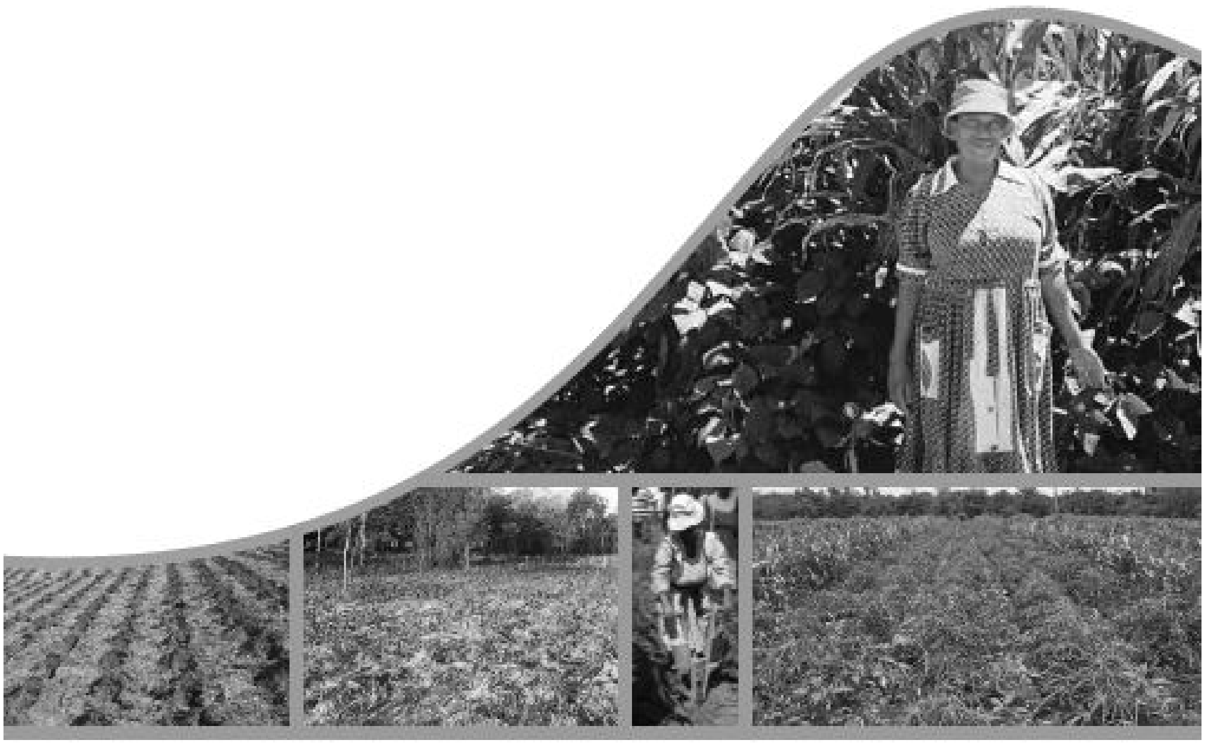

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Executive Summary

Conservation agriculture (CA) is a farming approach that fosters natural ecological processes to increase agricultural yields and sustainability by minimizing soil disturbance, maintaining permanent soil cover, and diversifying crop rotations. Construed more broadly, CA also encompasses natural resource management at the farm, village, and landscape scales to increase synergies between food production and the conservation and use of ecosystem services. As a context-sensitive management strategy, CA can include diverse practices such as livestock and fodder management, improved fallows, agroforestry, watershed management, and community protected areas.

This study reviews evidence on the practice, outcomes, and future potential of CA in sub-Saharan Africa as an approach to increasing food security, alleviating poverty, conserving biodiversity and ecosystem services, and supporting climate change adaptation and mitigation at local to global scales. The study was conducted by EcoAgriculture Partners in conjunction with CARE, WWF, and the World Agroforestry Centre to assist CARE, WWF, and their Alliance in developing an Africa-wide strategy for incorporating CA more effectively into their projects, programs, and policy advocacy work. Research methods included an extensive literature review, interviews, field visits to four CA projects in Tanzania and Mozambique, and critical analysis of these data to assess the most promising opportunities for CA in sub-Saharan Africa.

We found that CA is a particularly timely strategy for rural development and conservation in Africa. The continent currently faces multiple severe challenges associated with land degradation, rapid population growth, and climate change. For a variety of reasons, conventional Green Revolution agricultural development approaches have yielded disappointing results in many parts of Africa. Continent-wide, yields of staple crops such as maize have increased little—and in some cases even decreased—while land degradation, desertification, and climate change raise concerns that yields could drop even further in vulnerable areas. In this context, CA offers the promise of a locally-adapted, low-external-input agricultural strategy that can be adopted by the poorest and most vulnerable farming communities, as well as by those that can afford varying levels of mechanization and external inputs.

Despite its promise, however, CA adoption in Africa has been sparse. Continent-wide, CA is used on less than one million hectares, accounting for less than 1% of the total global area under CA management. Much of this total is attributable to commercial farmers and, outside of a few countries where it has been somewhat widely promoted (e.g., Ghana and Zambia), CA uptake among small farmers has been very limited.

In most places where it has been applied, CA has generated substantial benefits for farmers. Agricultural yields generally increase in the long-term (after 3-7 years), and very often increase in the short-term as well. Profitability typically increases, while labor demands usually decrease and become more flexible and less arduous. These benefits can be particularly important for women and vulnerable groups, such as those with HIV/AIDS. CA also helps to improve soil fertility and structure, capture and retain rainwater, and reduce erosion. Through such mechanisms, CA can increase the ability of smallholder farmers to adapt to climate change by reducing vulnerability to drought and enriching the local natural resource base on which farm productivity depends. For these reasons, CA should be considered to be a preferred approach to agricultural development for smallholder farmers in most regions of Africa.

There are several important issues and constraints associated with the practice of CA in sub-Saharan Africa. In many regions—especially those with high population density, low rainfall, or highly

degraded land—farmers may find it difficult to allocate crop residues and other biomass to mulching their fields, given competing demands for these materials for fuel, livestock fodder, and other purposes. CA usually involves a sharp departure from conventional farming practices and, as such, may require concerted training efforts and participatory engagement to overcome knowledge constraints and entrenched customs. CA may also require different farming inputs and implements than conventional agriculture, such as seeds for new cover crops and new hand tools or mechanical attachments. Finally, the benefits and costs of CA relative to conventional agriculture are likely to be different for men and women. Careful attention to gender dimensions—and to the heterogeneity of household needs and constraints—is important for adapting CA to maximize benefits at the individual and household levels.

Despite these potential challenges, CA for the most part increases synergies among food production, resource conservation, and sustainable livelihoods. To realize its full potential, however, CA should be implemented not just as a set of plot-scale agronomic practices, but as a more comprehensive approach that works at multiple scales. Under this approach, the core agronomic practices are supported by a variety of additional activities such as improved seed systems, micro-irrigation, post-harvest storage, composting, tree planting or agroforestry, market linkages, financial education and services, and establishment of farmers groups and participatory learning models. External inputs, such as fertilizers and herbicides, may also be used; however, since these are seen as synergistic with the agroecological approach of CA, smaller quantities are usually recommended. In this way, CA need not be fundamentally antagonistic to Green Revolution agricultural development strategies, but can be seen as a way of modifying such approaches to make them less input-intensive, more sustainable, and better adapted to climate change and other environmental stressors.

In contrast to its success as an agricultural development strategy, CA has not generally tended to produce substantial benefits for climate change mitigation (i.e., greenhouse gas emissions reductions or carbon sequestration) or conservation of biodiversity and ecosystem services. However, it is likely that these benefits could be achieved in the future, in many contexts, if the spatial scale and management framework for conducting CA were broadened to the watershed or landscape level. At the plot level, evidence indicates that CA can help sequester soil carbon, but at a relatively slow rate. Incorporation of perennial woody biomass (e.g., fruit trees, nitrogen-fixing fertilizer trees, and live fences) on farms can accelerate the rate of carbon sequestration. However, the greatest climate change mitigation benefits are likely to be realized by linking CA as a sustainable livelihood strategy to the reduction of deforestation and habitat degradation (e.g., through burning, logging, or shifting cultivation) in the surrounding area. Such spatial landscape management often requires deeper engagement in political, social, and governance issues, but can have significant payoffs in terms of co-benefits for watershed protection, biodiversity conservation, and sustainable livelihoods. Carbon finance projects based on this type of integrated landscape management may be financially viable in some instances, while there is little evidence that carbon finance based solely on plot-scale CA practices is financially viable at foreseeable carbon prices, without significant subsidies.

The design of CA projects to achieve benefits for climate change adaptation and mitigation, as well as poverty alleviation and ecosystem conservation, may require some departures from conventional project design. First, a longer project duration may be required because of the need for farmers and communities to relinquish entrenched agricultural practices (such as tilling or plowing), adopt new farming methods, and establish the knowledge base necessary to implement these new methods in a sustainable, self-reliant way. Given typical CA adoption trajectories and the possibility of short-term setbacks, the process of CA adoption in rural communities may take 3-5 years, while it may take even longer to build the capacity and confidence of farmer and community groups to become self-sustaining after the project ends. Increased project flexibility (e.g., in the design of logframes and indicators of success) can be helpful for responding to climate change or other perturbations as they arise. An explicit focus on adaptation planning—as has been initiated recently by CARE—can facilitate participatory appraisal, project design, monitoring, and staff training to support adaptation. Finally, as noted above, larger scale perspectives are often critical, and should be designed to balance the potential benefits of more comprehensive landscape management with the costs and challenges of such management.

With some exceptions, policy contexts in sub-Saharan Africa are not very supportive of CA. In most countries, there is little awareness of CA, and it has not been integrated into training curricula, extension services, or agricultural research programs. To the extent that they exist at all, subsidies and policies related to smallholder agriculture are more likely to discourage CA (e.g., by supporting tillage or subsidizing monocultures of preferred crops) than to encourage it. Customary land tenure may discourage long-term investment in soil fertility and ecosystem management. To address these constraints, additional investment in smallholder agriculture will be required. Fortunately, given the renewed interest in African food security in the past several years from both the African and international communities, there is hope that such investments may be realized. CA may be well-positioned to capture new funding sources since it can help meet multiple objectives, including climate change adaptation and mitigation as well as poverty alleviation, biodiversity conservation, and watershed management priorities. Advocacy and awareness-raising will also be critical to scale up effective CA in sub-Saharan Africa.

Looking to the future of CA in Africa, it is instructive to consider the history of CA in South America. Thirty years ago, CA was practically unheard of in South America. But, facing severe erosion problems and declining soil fertility, farmers in Brazil and elsewhere slowly began to experiment with CA. Grassroots innovation and knowledge sharing were gradually followed by the establishment of supportive local institutions and, eventually, national policies and programs to scale-up CA. After its slow beginnings, CA increased exponentially and now accounts for nearly 50 million hectares of farmland in South America. Africa is different than South America in many ways. But the experience of South America suggests that if CA can be demonstrated to be an effective and cost-efficient means of solving the continent’s current challenges—as it already has begun to be—then it has the potential to spread rapidly in the coming decades.

Introduction

By the mid-1990s, food security experts working in Zambia had come to the conclusion that the nation's smallholder agriculture was in crisis. Even under good circumstances—in years with suitable rainfall—many small-scale farmers could not produce enough food to sustain their families until the next harvest. At the same time, conventional farming practices were leading to progressively worse soil degradation, erosion, and deforestation. Poor nutrition, poor health, and land degradation perpetuated one another in a downward vortex.

Zambia's situation at that time was emblematic of much of sub-Saharan Africa then, and now. Existing farming practices across much of the region are not only unsustainably depleting the continent's resource base; they have been demonstrably ineffective at alleviating rural poverty. Cereal yields have remained nearly stagnant, averaging about 1.2 tons per hectare in Africa, compared to 3 tons per hectare in the developing world as a whole. Meanwhile, population has grown rapidly in many parts of the continent. About 30% of Africa's population—more than 200 million people—suffer from chronic hunger and malnutrition. Rural households throughout sub-Saharan Africa live on a razor's edge of survival, highly vulnerable to droughts, pest outbreaks, and market fluctuations that can spell disaster.

Efforts to introduce Green Revolution practices to Africa, following models that were successful across much of Asia, have yielded disappointing results. With weak institutions, poor market infrastructure, and limited access to capital throughout much of the continent, investment in Green Revolution technologies such as improved seeds, fertilizer, and irrigation has been extremely limited. Fertilizer use averages 8 kg/ha in sub-Saharan Africa compared to 190 kg/ha in the East Asia/Pacific region and a global average of more than 100 kg/ha (AGRA, 2010). African farmers also pay 2-6 times the global average price for fertilizer due to poor transport, low trade volumes, and lack of local fertilizer production (AGRA, 2010). Irrigation is used on only 3% of agricultural land in sub-Saharan Africa compared to more than 20% globally.

While most African nations and the global humanitarian community have not given up on bringing a Green Revolution to Africa, there is now growing interest in alternative agricultural development pathways that take an agroecological approach, invest in long-term soil health, require fewer external inputs, and help realize higher yields from those inputs that are applied. Such models, their supporters argue, are more often suitable for small farmers who cannot afford expensive external inputs or who produce food on fragile or degraded lands that must be nourished back to health and productivity.

In 1995, in an attempt to address the severe challenges of Zambia's small farmers, the Zambian Conservation Farming Unit (CFU) was established with the hypothesis that conservation agriculture (CA) could simultaneously help address problems of food insecurity and environmental degradation. Initial uptake was slow. Farmers were skeptical of the new practices, and the necessary tools and machinery were not readily available. The new approaches often required an initial investment of labor, and did not always register positive results away. But as more and more farmers reaped the fruits of higher yields and higher profits—especially in dry years—word spread and adoption increased. The number of small farmers practicing CA in Zambia rose from 20,000 in 2001 to 180,000 in 2009 (Giller et al., 2009). By the end of 2011, the CFU aims to increase adoption to 250,000 families, or about 30% of Zambia's small farmers. Most of these farmers have boosted grain yields, while in many cases reducing farm labor demands and decreasing susceptibility to drought.

The recent experience of Zambia begs the question: can CA provide equally transformative benefits across all of Africa? Many researchers and promoters have argued that it can, and major CA programs in a few other Africa countries (such as Ghana and Zimbabwe) have yielded very positive results. At the same time, however, significant challenges inhibit the effectiveness and dissemination of CA practice, even in some of the continent's most acclaimed CA success stories. These include shortages of capital and labor, strong adherence to traditional agricultural customs or practices, unclear or weakly enforced land and resource tenure laws, poor market access, and unsupportive policy frameworks. In addition, CA has not always been implemented in conjunction with the sorts of good agronomic practices (e.g., high-yielding seeds appropriate to the local environment) that may be necessarily to realize its true potential. Due to such limitations, some have argued that CA is appropriate in certain places and at certain times, but not necessarily as a broadly-applied agricultural development strategy. Others perceive CA as complicated and poorly tested in comparison to Green Revolution approaches that promulgate easy-to-follow recipes of improved seeds, fertilizer, and irrigation.

Study Background

As two organizations that work extensively in sub-Saharan Africa, CARE and WWF are both committed to supporting the development of rural landscapes that are environmentally and socio-economically sustainable. Historically, CARE approached this goal from the perspective of improving human wellbeing and reducing hunger and poverty, while WWF focused on environmental conservation, often in the context of human communities. However, through experience, both organizations have become convinced of the closely inter-related nature of these objectives: in rural areas where communities are dependent on natural resources for their livelihoods, lasting conservation strategies rarely ignore the needs of local communities. Conversely, the wellbeing of rural peoples depends heavily on the health of the local environment, including its biodiversity and ecosystem services.

Reflecting this reality, CARE now supports CA in several countries of sub-Saharan Africa—including Angola, Ghana, Lesotho, Liberia, Mali, Mozambique, Sierra Leone, Tanzania, Zambia, and Zimbabwe—with the goal of increasing crop yields and farmer incomes, improving the lives of vulnerable families and particularly women, and reversing the process of land degradation. More broadly, CARE has recently launched a major new initiative focused on climate change adaptation to help rural communities address the challenges to food security, human health, water availability, and declining natural resources that climate change may trigger. This initiative is implementing specific Community-Based Adaptation projects where vulnerability to climate change is a major threat to human wellbeing. It is also integrating climate change adaptation into CARE's work more widely, to ensure that investments in rural development increase communities' adaptability to climate change and do not inadvertently introduce new vulnerabilities or risks (CARE, 2010a). CARE has also initiated several agriculture, agroforestry, and REDD[1] projects that explore opportunities for farmers to receive payments for carbon sequestration as part of the voluntary carbon offset markets that are beginning to develop in Africa, while simultaneously conserving the natural resource base.

Meanwhile, WWF's approach to integrating biodiversity and environmental conservation with human wellbeing has been progressively evolving. Learning from the experiences of early Integrated Conservation and Development Projects in the 1980s and 1990s, the organization now works with rural communities in a variety of ways, often involving substantial local participation to develop resource management solutions. Recognizing that many biodiversity hotspots are located in close proximity to—or even in the midst of—cultivated areas, the organization now also works extensively with farmers including both large agribusiness and smallholder famers and their communities.

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[1] REDD stands for Reducing Emissions from Deforestation and Forest Degradation, and is one approach to offsetting greenhouse gas emissions.

Recognizing their shared objectives, CARE and WWF recently launched the CARE-WWF Alliance to collaborate in supporting sustainable rural landscapes in places where livelihoods and environmental conservation are mutually inter-dependent. In support of the Alliance, this study was commissioned to evaluate the ways in which CA and similar approaches could be used more widely and more effectively in the work of CARE and WWF to achieve multiple objectives, including:

- ensuring food security and adequate nutrition;
- reducing rural poverty;
- improving the resilience of agricultural systems and rural communities to climate change and other environmental variability;
- reducing greenhouse gas emissions, increasing carbon sequestration, and possibly generating marketable greenhouse gas offset credits; and
- conserving biodiversity and ecosystem services within agricultural areas and, by increasing the sustainability of sedentary agriculture, in nearby natural habitats and protected areas.

A Definition of CA for Sub-Saharan Africa

The term "conservation agriculture" is used differently by different practitioners, researchers, and promoters of the concept. Most of the definitions differ mainly in their degree of inclusiveness or specificity, such that the different conceptions of CA may be understood generally as a concentric set of domains (see Figure 1). A brief review of the most widely used definitions is worthwhile for formulating an appropriate definition for this study.

CA is conventionally and perhaps most commonly defined as a set of field-level agronomic practices encompassed by three principles:

1) **Minimizing soil disturbance** through direct seeding, minimal or no tillage, and avoidance of excessive compaction by machinery, draft animals, or humans;
2) **Maintaining permanent soil cover** through the use of cover crops, intercrops, and/or mulching provided by crop residues or other organic matter sources; and
3) **Diversifying crop rotations** to plant context-appropriate sequences of crops—often including nitrogen-fixing species—that help maintain soil health while reducing pest and disease problems.

This basic definition continues to be used by many researchers and practitioners (e.g., ACT, 2009; Kassam et al., 2009; Derpsch et al., 2010; FAO, 2010a), and has been adapted or applied to develop context-appropriate agronomic practices for specific regions of the world. For instance, in Zambia these principles have been expanded into six basic conservation farming "technologies" that include retaining crop residues, concentrating tillage and fertilizer application in a permanent grid of planting basins or series of planting rows, completing land preparation in the dry season, weeding aggressively to reduce plant competition, and inter-cropping or rotating nitrogen fixing legumes on up to 30% of the cultivated area (CFU, 2010). As practiced in the Protracted Relief Program in Zimbabwe, CA involved carefully-timed weeding and application of both organic and inorganic fertilizers (Mazvimavi and Twomlow, 2009). In dry regions of East Africa, the Regional Land Management Unit (RELMA; now defunct) developed an "African-style" CA approach that downplayed the importance of year-round soil cover (which is sometimes infeasible in dry environments) and instead developed practices to increase water use efficiency and improve soil fertility through targeted fertilizer applications (RELMA, 2007).

Underlying all of these CA principles and practices is the notion that agriculture should nourish and enhance the natural biological processes that support soil fertility, nutrient cycling, and hydrological cycling. These ecosystem services, in turn, benefit farmers by boosting crop yield, reducing the need for external inputs, increasing farm profitability, and reversing land degradation. CA is thus closely aligned with the concept of agroecology, in which farms are deliberately managed to foster beneficial ecological processes and disrupt detrimental ones. However, CA does not exclude the use of external inputs; in fact, as applied in the Americas CA tends to be relatively input-intensive. In Africa, CA used in conjunction with modest levels of external inputs can help boost the yield response to the inputs applied (see Box 1).

Box 1. CA and Good Agronomic Practice Go Hand-in-Hand

Conservation agriculture is often presented as an alternative to conventional Green Revolution-style agricultural intensification. It is important, however, not to misunderstand the nature of this distinction. First, CA does not represent the lack of agricultural intensification, but rather intensification along a different pathway, based on agroecological management of soil, water, nutrients, plants, and animals. Second, the success of both CA and conventional agricultural intensification typically depend on a largely overlapping set of good agronomic practices, including:

- selection of context-appropriate, high-yielding seed varieties;
- optimal and accurately-applied seed spacing and seed density;
- precise and judicious application of fertilizers (whether organic or inorganic) in the optimal locations and quantities;
- context-appropriate crop rotations designed to break pest and disease cycles and prevent the exhaustion of soil nutrients; and
- introduction of new agricultural technologies through culturally appropriate, participatory means of communication, education, and training

Without the use of these standard good practices, neither CA nor Green Revolution-style agricultural intensification is likely to realize its full potential for increased yield, profit, or human wellbeing.

Many of the more recent conceptions of CA move beyond soils and annual crops—and sometimes beyond the plot scale—to include other farm elements that affect productivity and resource sustainability. In Zambia, for instance, the Conservation Farming Unit is now using the term "conservation farming" to refer strictly to the principles and practices stated above, while the term "conservation agriculture" is used more broadly to include complementary perennial vegetation on farms such as fruit trees, fertilizer trees (i.e., nitrogen fixing trees such as *Faidherbia albida*), and live fences (CFU, 2010). The FAO (2010b) has found these types of agroforestry practices particularly compatible with CA. Drawing on the experiences in Zambia and in maize agroforestry systems in neighboring Malawi, the World Agroforestry Centre is now promoting a form of CA called "Evergreen Agriculture" that combines the basic agronomic principles of CA with a progressive introduction of diverse perennial vegetation, especially fertilizer shrubs and trees (ICRAF, 2009). One important part of traditional CA systems—now much less common due to population pressures and small farm sizes—is the use of rotational fallows, either for 1-2 years with nitrogen-fixing shrubs or for a longer period with natural successional vegetation.

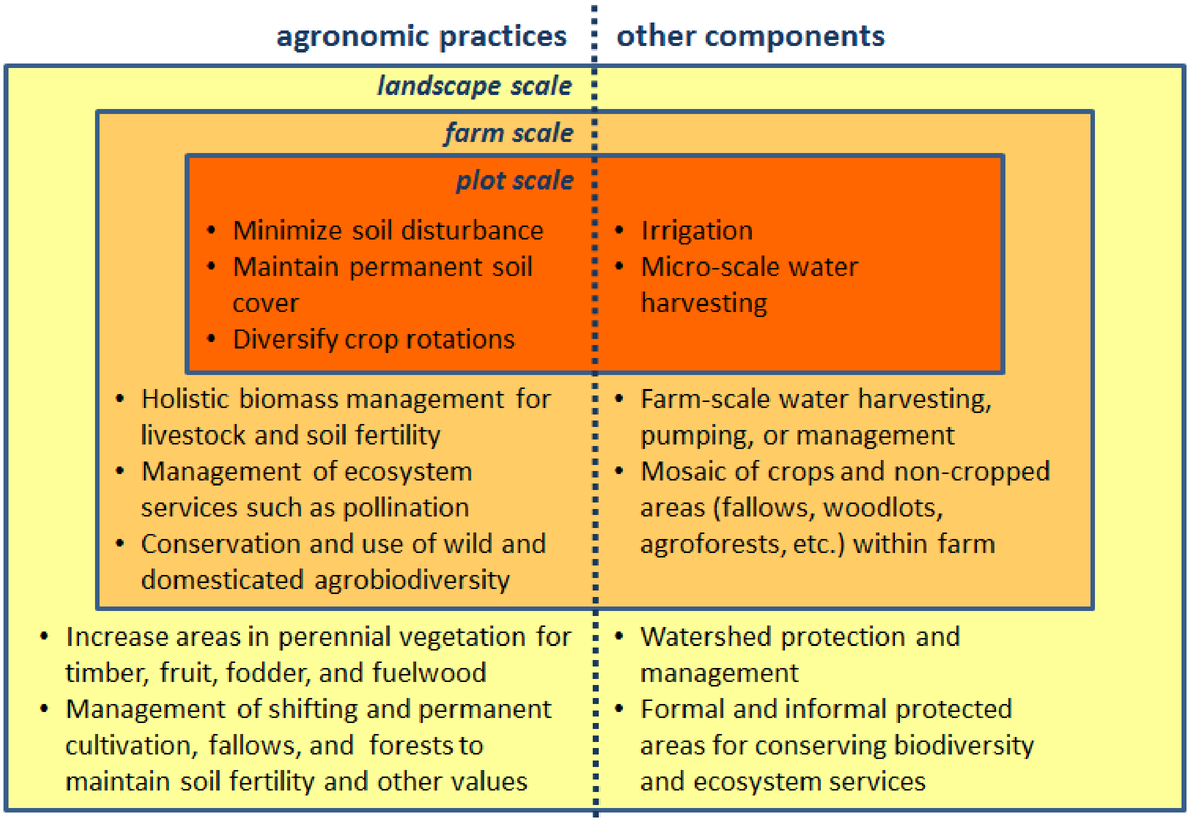

Figure 1. Alternative conceptions of conservation agriculture and their major foci and scale of implementation. As traditionally defined, CA encompasses a set of resource-conserving plot-scale agronomic practices (inner-most box). Recent implementation of CA in smallholder settings often takes a more integrated approach to management across multiple plots, including perennial trees and shrubs, livestock, fallows, and wooded areas (middle box). At a larger scale (outer-most box), ecoagriculture, integrated watershed management, and other landscape scale approaches address conservation, food security, and land regeneration in the context of land-use mosaics, wildlife habitat, protected areas, and watershed functions. Even broader views that consider political, economic, institutional, and market variables can also be valuable. Variables indicated at each scale are illustrative examples, not a comprehensive list.

While the integration of perennial vegetation and other farm components is important for assessing and managing resource use and conservation, many of the variables that are most critical for climate change adaptation and mitigation are mediated at larger scales, beyond individual farms or even clusters of farms. For instance, water availability on individual farms may depend on upstream land uses. Conversely, the long-term fertility and viability of farm plots may determine whether farmers feel compelled to abandon their plots open up new areas of natural habitat for agricultural production, or to supplement their incomes through activities such as wildlife poaching or charcoal production. These broader relationships are considered in the practice of “ecoagriculture,” which takes a landscape-scale perspective to resource management and regeneration to maximize synergies between food production, ecosystem conservation, and human livelihoods. There is no doubt that smaller scales are sometimes both more relevant and more manageable for farmers and rural communities. However, in the context of this study, a landscape perspective is important for assessing opportunities for climate change adaptation and mitigation as well as synergies and tradeoffs between these goals and those of food security, increased crop yields, and ecosystem conservation.

For the purpose of this study, therefore, we consider CA to include relevant practices at multiple scales, and their interactions (see Figure 1). These include:

- Plot or field scale management of soil and soil fertility, agricultural inputs, biomass, tillage and planting practices, crop rotations, and cover crops;
- Farm scale management of diversified annual and perennial vegetation, and of water resources including natural water bodies, wells, and water harvesting structures; and
- Community- to landscape-scale management of cultivated areas in relation to water resources and associated non-cultivated land areas such as private or community forests, woodlots, grazing areas, and protected areas.

As applied in practice (including in all of the CARE and WWF projects surveyed for this study), CA projects implemented by NGOs tend to include not only farm and landscape management, but also a supporting cluster of activities that are important for institutionalizing CA as a sustainable livelihood strategy. (See Table A1-1 in Appendix 1 for a summary of the context, goals, and major activities in some current and recent CARE and WWF CA projects in sub-Saharan Africa.) Most of these activities are considered part of the rural development "toolbox," and few are uniquely associated with CA. Thus, although such activities are not generally considered to be part of the definition of CA, it is helpful to understand them as an "expanding orbit" of supporting mechanisms that can help scale-up the adoption of CA and ensure that initial project investments lead to long-term livelihood gains and self-sufficient rural communities (see Figure 2).

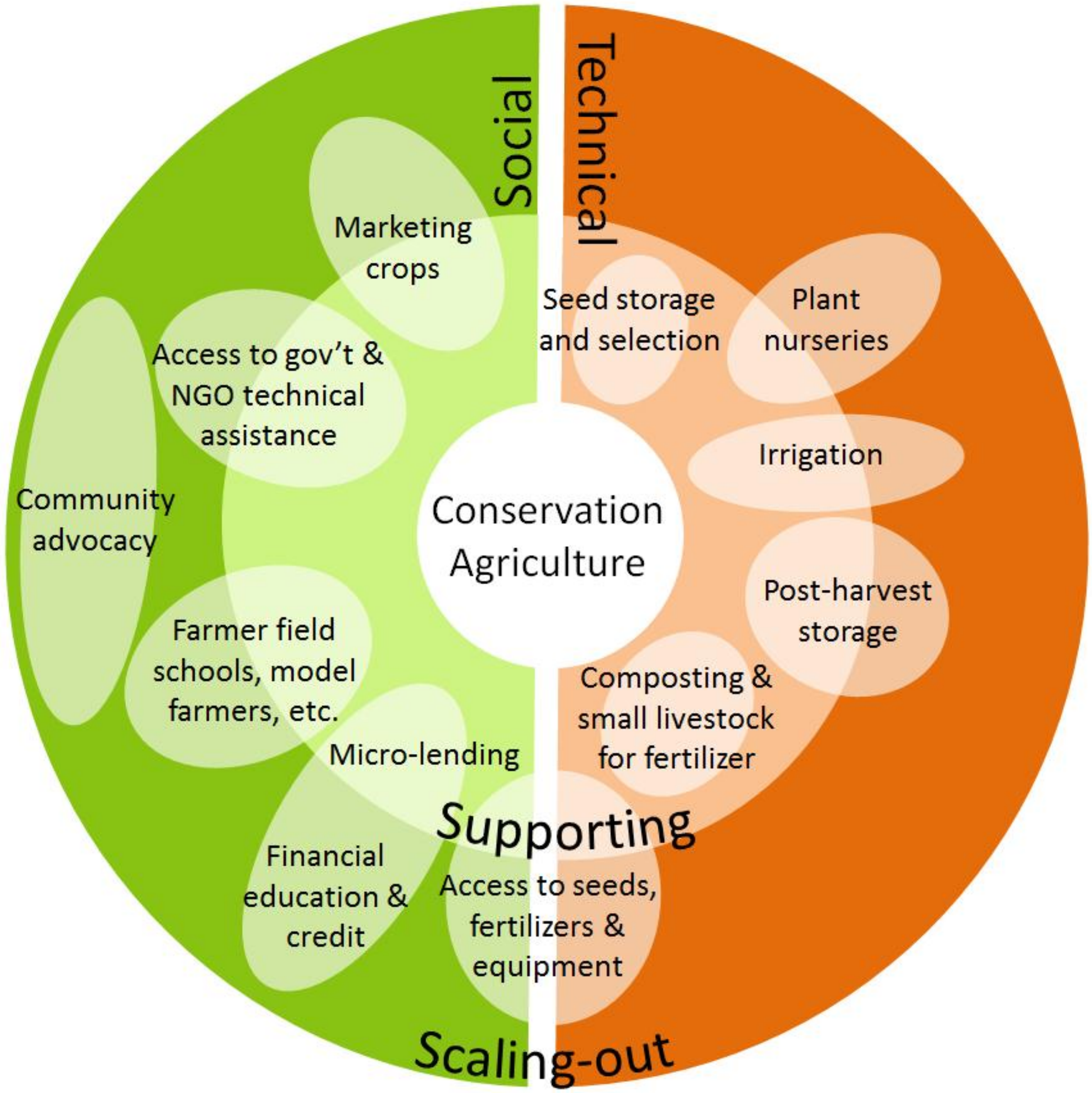

Figure 2. "Expanding orbits" of practices, activities, and institutions that can enhance the scale and effectiveness of conservation agriculture as a sustainable livelihood strategy. Social factors (left side of the diagram, shaded green) and technical factors (right side of the diagram, shaded orange) associated with the practice of CA either provide direct support to field level activities (inner orbit) or opportunities to scale-out CA throughout communities and landscapes (outer orbit).

Project Scope and Approach

This research project had four key objectives: 1) to review current CA practices and their impacts; 2) to evaluate the associated benefits of these practices for climate change adaptation and mitigation; 3) to assess the effectiveness and benefits of CA in an illustrative sample of CARE and WWF projects; and 4) to identify opportunities to enhance these benefits through future modifications in project, program, and policy design.

Study Methodology

The study methodology included six components: 1) literature review; 2) desk review of CARE and WWF CA projects; 3) field visits to four CARE and WWF CA projects in sub-Saharan Africa; 4) assessment of opportunities and constraints for participation in carbon markets; 5) project and program design recommendations; and 6) policy recommendations. Each of these is components is described briefly below.

Literature Review

The project team reviewed the existing peer-reviewed literature and grey literature to amass evidence on the performance on CA and its potential for climate change adaptation and mitigation. The focus of the review was on literature and case studies from sub-Saharan Africa. However, for certain topics where the state of knowledge is much more advanced in other regions of the world (particularly South America), the team reviewed this literature as well. Given the multifarious nature of CA and the importance of understanding its various agronomic and socio-ecological dimensions, the review spanned many topic areas, including:

- Review and synthesis of experience with CA, including its global and regional expansion and key supporting institutions;
- Evidence on CA yields compared to yields of conventional systems;
- Specific dimensions of CA and their relation to system outcomes—including soil management, water management, and crop rotation and management;
- Evidence on CA adoption and factors influencing adoption;
- Technical and economic potentials to sequester carbon and reduce greenhouse gas emissions in agroecosystems;
- Carbon finance and carbon markets, particularly those involving African smallholders;
- Impact of CA on environmental conservation and biodiversity;
- Frameworks and methods for assessing agroecosystem resilience and adaptability;
- Economic and financial aspects of CA, including profitability and investment needs;
- Methods for monitoring and evaluating CA and its outcomes; and
- CA case studies and evidence from smallholder settings in sub-Saharan Africa.

Review of CARE and WWF CA Activities in Sub-Saharan Africa

The team conducted interviews and e-mail questionnaires to survey CARE and WWF activities involving CA or sustainable agriculture in different parts of sub-Saharan Africa. The purpose of this work was threefold: 1) to understand the current range and scope of CA activities conducted by these organizations; 2) to characterize the types of practices and methods being promoted at the field level;

and 3) to assess the climate change adaptation and mitigation outcomes of existing projects. The team surveyed all eight of the CARE CA projects supported by the Howard G. Buffett Foundation (including projects in Angola, Ghana, Liberia, Mali, Mozambique, Sierra Leone, and Tanzania) as well as other CA activities in Zambia. E-mails to WWF staff in the US, UK, and several country offices turned up relatively few CA or sustainable agriculture projects in sub-Saharan Africa.

Field Visits

In November 2010, lead author Jeffrey Milder visited four CARE and WWF CA projects in southern Africa to understand in greater detail the scope and approach of each project; assess each project in relation to a climate change adaptation and mitigation evaluation framework; review project data; interview participating farmers, project managers, and extensionists; assess the political, institutional, and market contexts in which each project operates; and identify opportunities for increasing project benefits, scaling-up successes, and applying lessons learned to other contexts. The field sites included:

- **Uluguru Mountains, Tanzania:** Two projects in this area were visited. The Hillside Conservation Agriculture Project (HICAP) supports 4,400 households to implement CA and associated community development activities to support food security, while protecting surrounding forests and watersheds. The Equitable Payment for Watershed Services (EPWS) project promotes CA, agroforestry, and farm terracing to help increase food security, reduce erosion, and encourage re-forestation in a critical sub-catchment that contributes to Dar Es Salaam's public water supply.
- **Quirimbas National Park, Mozambique:** This WWF project supports sustainable agriculture in the communities pre-existing within the national park to help improve the viability of sedentary agriculture and thereby minimize pressure to destroy or extract resources from sensitive habitat areas while also reducing human-wildlife conflict.
- **Inhambane, Mozambique:** This CARE project seeks to raise crop yields and household incomes in a drought-prone area by helping farmers improve soil fertility, seed systems, and water management systems.

Analysis of Carbon Market Opportunities and Constraints

Based on the literature review and on EcoAgriculture Partners' recent review of agricultural carbon projects and opportunities in sub-Saharan Africa, the project team evaluated the feasibility of various options and opportunities for engaging small farmers and rural communities in carbon finance projects at CARE and WWF project sites. The analysis considered the technical potential for carbon sequestration and emission reduction in different agroecosystems, as well as the feasibility of participation in carbon offset projects relative to economic considerations, household decision-making factors, and the role of institutions and intermediaries.

Design, Programmatic, and Policy Recommendations

Program and policy options and recommendations were developed based on three main sources of input: 1) interviews with CARE and WWF staff (including staff from African country and field offices), public officials, and donors engaged in CA; 2) assessment of key policy and structural opportunities, limitations, and barriers from field research and interviews; and 3) reviews of the broader policy and investment contexts for climate change adaptation and mitigation, ecosystem conservation, and food security.

Study Questions

Using the previously-described methods, the study sought to address the following six key questions, the answers to which are critical for designing future CA projects and programs that meet CARE's and WWF's objectives:

1. Are CA projects significantly increasing farmers' ability to adapt to current climate variability and future climate change?
2. Are CA projects as currently designed sequestering significant net amounts of carbon that may provide opportunities for revenue generation through the sale of carbon offsets? What is the order of magnitude contribution of different agroecosystem components to potential net carbon sequestration?
3. How could CA projects be modified to enhance their value for climate change adaptation and mitigation?
4. How could the design and implementation of CA be modified to enable it to generate eligible, cost-effective carbon credits for the voluntary market in an equitable way without compromising the other benefits that these projects can provide?
5. What are the key synergies and tradeoffs among different objectives of the CARE-WWF Alliance, including climate change adaptation, climate change mitigation, food security, poverty alleviation, and environmental protection?
6. What are key policy priorities for enhancing climate change adaptation and mitigation in CA programs? Of these priorities, which ones is the CARE-WWF Alliance best positioned to support?

Literature Review: An Overview of CA in Africa

This chapter provides a synthesis of published research on CA in Africa, including its current scale, adoption rates and dynamics, evidence on key outcomes and impacts, and principal constraints and opportunities for scaling up. The overview presented here provides a context for the more detailed examination of the six study questions in the next two chapters.

CA Adoption Worldwide and in Africa

According to multiple estimates, CA in 2009 was practiced on roughly 110 million ha worldwide, or approximately 6-7% of the world's total cropland. Derpsch and colleagues (2010) estimate that no-till agriculture (which they equate with CA) was practiced on nearly 116 million ha in 2009, and is increasing at a rate of six million ha per year (see Table 1). Kassam and colleagues (2009) distinguish no-till agriculture from CA (which they define as involving no-till or minimal tillage plus permanent soil cover and diversified crop rotations), and estimate that CA was used on 106 million ha worldwide in 2009. Africa has by far the lowest portion of area under CA or no-till farming, accounting for only about 0.3% of the world total (see Table 1).

Table 1. Area under no-till farming by continent, as of 2009. Source: Derpsch et al., 2010.

Continent	Area (ha)	Portion of total worldwide CA area (%)
South America	49,579,000	46.8
North America	40,074,000	37.8
Australia and New Zealand	17,162,000	11.5
Asia	2,530,000	2.3
Europe	1,150,000	1.1
Africa	368,000[a]	0.3
World total	115,863,000	100

[a] There are large variations in estimates of the scale of CA activity in Africa (see below). The area stated in the Derpsch study cited here is likely a low estimate, as South Africa alone is reported by other sources to have 368,000 ha under CA.

CA adoption rates vary widely by country in Africa (see Table 2). CA is a growing movement in eastern and southern Africa, with numerous activities and promotion programs by government agencies and civil society alike. For example, FAO (2010c) reports that twelve countries have identified CA Focal Points to promote and coordinate CA activities (Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe). Most of these countries have established multi-stakeholder task forces that include the CA agenda. While CA is also practiced in other parts of Africa (e.g. Burkina Faso, Morocco, Niger, and Tunisia), promotion and adoption tend to be limited. CA in Ghana is significant, but stagnated after donor funding and promotion ended.

Estimates of the scale of CA activity in Africa—and the number of households practicing CA—vary substantially. Part of the difficulty in estimating adoption has to do with defining criteria for what constitutes adoption. There are many situations where the CA "package" is not implemented fully or with sufficient intensity to be included in some CA statistics. In Zambia and Zimbabwe, for instance, farmers who adopt CA tend to do so partially or incrementally, or adopt CA on some of their plots but not others (Haggblade and Tembo, 2003; Mazvimavi and Twonlow, 2009). For example, approximately 30% of smallholders in Zambia have adopted elements of CA (CFU, 2010), but only 25% of farmers are reported to be following all three core CA principles (minimal soil disturbance, continuous soil cover, and crop rotations) (Baudron et al., 2007). Even when all three CA principles are adopted, they might not be implemented in a manner consistent with recommendations: for instance, a farmer might maintain 10% soil cover (not 30%) or continue tilling his or her land, but with reduced frequency. In Zambia, many farmers have started to use planting basins, but move the location of these basins from year to year, thus negating much of the potential soil fertility benefit of this practice (L. Gatere, Cornell University, pers. comm.). In some cases, partial adoption of CA is a step toward full adoption, while in other cases it is an ongoing practice for farmers who mix and match diverse farming techniques as they see fit. Figure 3 depicts four different pathways to CA adoption; in Africa, pathways 2-4 (forms of partial adoption) are more common than pathway 1 (quick and complete adoption).

Table 2. CA adoption in Africa, including total area under CA management and numbers of smallholders adopting CA practices. Pairs of numbers separated by the "/" symbol indicate estimates from different studies. Sources: RELMA, 2007; Kassam et al., 2009; Thiombiano and Meshack, 2009; Derpsch et al., 2010.

Country	Area under CA (ha)	Number of smallholders conducting CA
Ghana	30,000 / 300,000	Up to 400,000
Kenya	15,000 / 18,000	5,000
Malawi	47,000	5,400
Morocco	4,000	No data
Mozambique	9,000	No data
South Africa	368,000	No data
Sudan	10,000	No data
Tanzania	6,000	No data
Tunisia	7,000	No data
Zambia	40,000 / 110,000	70,000 / 100,000
Zimbabwe	7,500 / 15,000	No data

The rate of adoption varies according to farm size, with large commercial farms comprising most of the area under CA globally and in parts of Africa. In eastern and southern Africa, CA has been adopted by many large commercial operators, but the extent of adoption among smallholders is not well documented in most countries and, with a few exceptions, is estimated to be very low. CA adoption in Kenya is growing among large-scale operators, but growth is minimal among smallholders (Kaumbutho and Kienzle, 2007). As mentioned in the Introduction, Zambia is one country that has achieved high rates of smallholder adoption; the Zambian CFU predicts a 30% adoption rate among smallholders nationwide by 2011.

CA adoption often relies on a donor project or combination of "push" and "pull" factors to motivate a change from the status quo (Baudron et al., 2009). For instance, farmers may turn to CA when the knowledge and resources to do so are adequate and appealing ("pull") and when a crisis or set of substantially new conditions requires a response ("push"). Push factors may include high food prices, food insecurity, natural disasters, environmental regulation, rising input and energy costs, or climate change. Vulnerable smallholders in Africa are particularly unlikely to adopt CA spontaneously, but there is some evidence that farmers who have lower risks have adopted CA without external incentives, especially by learning from neighbors (Mazvimavi and Twomlow, 2009).

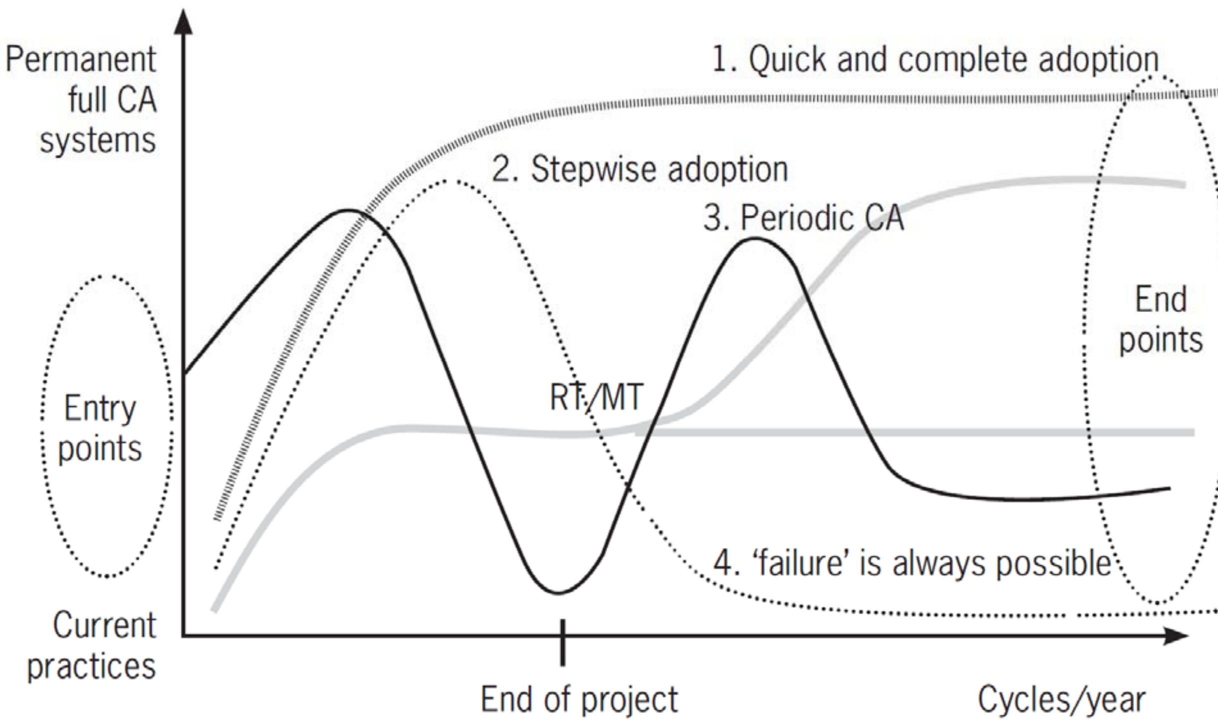

Figure 3. Four pathways to CA adoption: 1) quick and complete adoption of CA as recommended; 2) stepwise adoption of CA practices, which may or may not lead to complete adoption over time (RT = reduced tillage, MT = minimum tillage); 3) CA practiced during some farming cycles but not others; and 4) use of CA practices stops soon after the end of the project, perhaps because incentives are no longer provided. Source: Baudron et al., 2007.

CA is promoted in Africa by various stakeholders, including governments, international donors, NGOs, and the private sector. Key promoters of CA are described below.

Continent-wide institutions: Several major African regional partnerships and initiatives now include CA as an integral part of their rural development strategies. The African Conservation Tillage Network (ACT) is perhaps the foremost regional institution in this field. ACT is a pan-African NGO whose voluntary membership aims to bring together stakeholders, share knowledge, and foster collaboration to improve agricultural productivity through the sustainable use of land and water resources in Africa's farming systems. A more recent supporter of CA is the Alliance for a Green Revolution in Africa (AGRA), which works to achieve food secure and prosperous African communities through the promotion of rapid, sustainable agricultural growth based on smallholder farmers. CA has also been incorporated into the regional agricultural policies of the New Partnership for Africa's Development (NEPAD).

International donors and organizations: Key donors and international organizations that have promoted CA in Africa include the FAO, Swedish International Development Cooperation Agency (SIDA), Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), the World Agroforestry Centre (ICRAF), IITA, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Danish International Development Agency (DANIDA), European Union, and the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT).

International NGOs conducting CA projects include CARE, WWF, Oxfam, and others. Appendix 1 summarizes some illustrative CARE and WWF CA projects in sub-Saharan Africa.

Evidence on Key Outcomes of CA in Africa

Overall there is significant agreement and empirical evidence that CA can deliver substantial benefits to small farmers. This sub-section reviews the empirical evidence on the effects of CA management in sub-Saharan Africa on five key outcome dimensions: crop yields, farm profitability, labor demand and supply, gender dimensions, and conservation of biodiversity and ecosystem services. Please see Table A2-1 (in Appendix 2) for specific examples of key outcomes of 13 illustrative African CA projects. Together with the subsequent assessments of climate change adaptation and mitigation outcomes of CA, the review of evidence presented here informs this study's analyses of synergies, tradeoffs, and promising options for future project and program development.

Yield

Numerous studies have been conducted to compare the yields of CA systems to those of conventional farming systems. The general pattern from this research is that yields increase in both the short- and long-term as a result of CA. Recent reviews of research in Latin America, Africa, and Asia have concluded that CA yields are approximately 20-120% higher than those in conventional agriculture (Kassam et al., 2009; Derpsch et al., 2010). In Africa, numerous studies have also documented yield increases associated with a shift to CA practices across a range of geographies and crops. For instance:

- Kaumbutho and Kienzle (2007) found that in the Laikipia district in Kenya yields in maize, wheat, potato, and bean were 50-200% higher in CA than in conventional systems.
- Boahen et al. (2007) reported that maize yields in Ghana were up to three times higher with CA than in traditional slash-and-burn systems.
- According to Shetto et al. (2007), yields increased by 93-360% in maize and sunflower CA systems in Tanzania following adoption of conservation tillage (ripping) and a mucuna cover crop.
- In Uganda, conventional systems have a grain yield of about 2,500 kg/ha, but yields increase to 3,000-3,100 kg/ha under different CA methods (Nyende et al., 2007).
- FAO (2010b) also found significant yield increases in Zimbabwe across several crops, including maize, sorghum, millet, cowpea, and soybean.
- When examining CA yields in Malawi, Mloza-Banda and Nanthambwe (2010) found that maize grain yields from CA were between 294% and 477% higher than yields in traditional systems in 2000/2001 and 394% to 609% higher in 2001/2002 across six different Agricultural Development Divisions.
- In Zambia, yields on farms using CA practices doubled in maize plots and were 60% higher for cotton, as compared to conventional plowing systems (Haggblade and Tembo, 2003).
- Based on a meta-analysis of 94 peer-reviewed publications from all regions of sub-Saharan Africa, Sileshi and colleagues (2008) determined that maize yields increased significantly through the use of rotations or intercropping with woody or herbaceous legumes (which are commonly a component of African CA). Yield increases averaged 1.6 t/ha for coppiced woody legumes, 1.3 t/ha for non-coppiced woody legumes, and 0.8 t/ha for herbaceous green manure legumes.

While yield increases can be substantial, they depend on local conditions. There can also be considerable year-to-year variation in the yield benefits provided by CA, depending on weather. For example, in commercial maize systems in Zimbabwe, yield benefits were recorded in normal and dry years, but not in wet years (Giller et al., 2009).

There are several mechanisms by which CA can improve yields in sub-Saharan Africa, and these often work in synergy. Mulching and residue management can increase soil fertility and nutrient availability to plants, which is one of the surest ways to boost production of nutrient-hungry crops such as maize. Improved water availability throughout the cropping cycle is another key mechanism. Also important in seasonally dry climates is the ability to seed crops immediately after the rains begin, thus accelerating the crop growth cycle and maximizing utilization of rainfall during a short rainy season (FAO 2010d). Complementary practices such as the use of context-appropriate high-yielding seeds, appropriate seed spacing and densities, use of inorganic and/or organic fertilizers, and improved pest management practices can increase the yield gains associated with improved soil, residue, and water management (see Box 1).

There is some disagreement in the literature about the magnitude and consistency of the yield gains associated with CA. Much of this disagreement, however, stems from mainly sematic distinctions about the definition of CA and the baseline farming system again which it is compared (see Box 2).

Box 2. Conservation Agriculture and Its Discontents: Critiques and Responses

Several of the most commonly cited critiques of CA and the published literature on CA are described in a 2009 paper by Giller and colleagues. These critiques include:

1. CA has not been critically analyzed to a sufficient degree. The empirical evidence for increased yields, reduced labor needs, improved soil fertility, and reduced erosion is inconclusive and/or unclear.
2. Because CA constitutes an integrated set of farming practices and can take many different forms, it is difficult to determine which CA principles or practices actually contribute to the desired effects.
3. Evidence of adoption has been exaggerated and what constitutes “true” adoption is unclear. CA is often said to be applicable to almost any type of environmental conditions, but testing of this assumption has been insufficient.

The paper by Giller and colleagues has generated extensive discussion among conservation agriculture practitioners and promoters, some of which is compiled in the International Conservation Agriculture blog (http://conservationag.wordpress.com/). Some of the main responses and counter-arguments to the issues raised by Giller and colleagues are summarized below:

1. The evidence base on CA is extensive, especially for South America and North America, and much of this evidence is applicable to other parts of the world. There is significant agreement and empirical evidence that CA can deliver substantial benefits to small farmers, as detailed in this report. Experts acknowledge that CA benefits and constraints depend on the context and the timeframe for analysis. For example, there is little disagreement that CA usually improves yields in the long-term, as attested to by its widespread voluntary adoption in places where it has been supported by appropriate knowledge systems and access to inputs. However, short-term effects on yield, labor demand, and other factors is context-dependent, although there may be consistent patterns that tend to hold true within specific regions and cropping systems.

2. The debate surrounding the criticism that it is difficult to determine the outcomes of different CA principles and practices frequently boils down to a matter of differing definitions and research designs. Since CA cannot be practiced in the absence of other agronomic practices (e.g., selection of seed varieties, seed spacing, use or non-use of external inputs, etc.) it is indeed sometimes difficult to tease apart the effects of the CA practices from the effects of other management dimensions within a cropping system. The criticism presented by Giller and colleagues (2009) is valid insofar as many of the published studies on CA compare traditional smallholder farming practices involving many poor agronomic practices to CA with good agronomic practices. The nature of these comparisons makes it difficult to de-couple the yield gains attributable to good agronomic practices from those attributable specifically to CA. A more scientifically valid comparison would be between two or more alternative intensification pathways, including one through CA and one through conventional agriculture based on standard tillage and the use of external inputs. However, given that input-intensive development pathways may not be available to many African small farmers, the comparison of traditional smallholder methods to CA that includes good agronomic practices (see Box 1) is indeed a relevant analysis that sheds light on the efficacy of CA as a form of investment in agricultural development.
3. There is general agreement about the rates of CA adoption around the world, but estimates differ somewhat because of differences in the definition of what constitutes adoption. Particularly in Africa, there are many cases in which the CA package is not implemented comprehensively or permanently. Some authors include such incomplete adoptions in their statistics, while others do not. However, these differences do not materially change the nature of the conclusions about the order-of-magnitude scale or trajectory of CA adoption in Africa or elsewhere.

Most people within the international CA community agree that CA is not the only solution to poor productivity, environmental degradation, and poverty, but it may be the most feasible and most sustainable solution for many cropping systems, especially for smallholders within little ability to intensify following a conventional Green Revolution trajectory. Debates such as the ones summarized here have generated valuable dialogue and clarification within the CA community, but have not significantly undermined interest in expanding and improving the science and practice of CA around the world.

Profitability

The profitability of CA is almost always higher than that of conventional agriculture, based on the several studies and cases from sub-Saharan Africa that we reviewed. For example:

- A FAO (2010a) budget analysis in Zambia and Zimbabwe demonstrated that returns under CA are significantly higher than under conventional systems. In Zambia, annual returns were US$104/ha under CA and US$19/ha under conventional tillage. In Zimbabwe, returns were US$213/ha under CA and US$61/ha under a conventional system.
- According to Shetto and Owenya (2007), net benefits in Tanzania maize systems were found to be 34,500 Tanzanian shillings (TZS) per ha on conventional farms versus 213,050 TZS/ha on farms practicing CA. These figures were 89,350 TZS/ha versus 416,450 TZS/ha for sunflower. This analysis took into account weeding, labor, fertilizer, and implement costs.
- Boahen and colleagues (2007) report that in Ghana, the net return for CA was 145% higher than for slash-and-burn agriculture, taking into account yield differences as well as the costs of land rent, seed, fertilizer, herbicide, labor, and transport.

- Thiombiano and Meshack (2009) report that in Kenya, input costs in CA were only 35% of those on conventional farms, while the yield doubled.

The increased profitability of CA tends to be a result of higher yields, lower expenditures on energy and other inputs, and sometimes a reduction in labor costs (FAO, 2008; Derpsch et al., 2010). In addition to labor, the major costs associated with CA are for equipment, seeds, and herbicides. In the long-term, CA equipment tends to be less expensive than equipment for conventional agriculture because it lasts longer, is less expensive to maintain and repair, and consumes less fuel (for power-operated machinery) (Apina, 2009). Friedrich and colleagues (2009) estimate that CA can reduce the cost of mechanization by 50% relative to conventional agriculture. Similarly, CA typically reduces the cost of purchased fertilizer by substituting nitrogen-fixing plants and improved soil biological processes as indigenous sources of soil fertility. In Malawi, for instance, nitrogen-fixing *Faidherbia albida* trees have been found to reduce the need for inorganic nitrogen fertilizer by 75%, resulting in a substantial reduction in input costs (Akinnifesi et al., 2010).

Labor

The availability of farm labor is a major constraint and decision factor in most smallholder production systems. In many parts of Africa, labor demand tends to be greater than supply, at least seasonally. Labor is often in short supply due to rural to urban migration (especially by young men), prevalence of HIV/AIDS and other diseases, and under-nutrition and malnutrition. Disease and poor health increase dependency ratios (i.e., the ratio of non-working persons to working persons), which are higher in sub-Saharan Africa than in any other region of the world (Radeksz, 2010).

When analyzing the labor implications of CA, it is more helpful to disaggregate effects by task, season, agroecological context, gender, and time since adoption than to try to make broad generalizations. For instance, in many areas, CA requires deep-digging to penetrate soil crusts—a task that is very arduous and may increase the initial labor requirement for land preparation. In other areas, however, land preparation in CA requires less labor than in conventional agriculture since whole-field plowing or tillage is not required. Soil type also affects the direction and magnitude of these differences. Finally, even if total labor is less under CA, labor requirements for women may be greater, or vice versa (see “Gender Dimensions” below).

In the long-term, CA very often reduces the labor required for farming, relative to conventional practice, although this is not universally the case. In the short-term, it is quite common for CA to require increased labor, especially for weeding and land preparation. Tillage is an efficient way to control weeds, but with reduced tillage, weeding can require substantial initial increases in labor if herbicides are not used. Unexpected labor peaks can also occur at harvest time due to increased yields from CA.

Following are some recent findings on labor needs in CA compared to conventional systems in sub-Saharan Africa. As these results indicate, the labor implications of CA are highly context-specific depending on the crop, agroecological context, number of years since adoption, and the nature of the farming system practiced previously. Thus, any efforts to extrapolate such findings to other contexts should proceed cautiously.

- In Tanzania, the time required for land preparation, planting, and weeding was 50-75% lower in CA than in conventional agriculture (Shetto and Owenya, 2007).
- In Zambia, CA using planting basins nearly doubled the required weeding effort compared to the conventional method that included plowing (Baudron et al., 2007).

- Examining CA cotton systems in Zambia, Haggblade and Tembo (2003; cited in Baudron et al., 2007) found that the number of workdays required for weeding nearly doubled (from 45 to 80), while the number of days required for land preparation increased nearly tenfold (from 7 to 66) relative to conventional agriculture.
- Taking into account all land preparation, planting, weeding, and harvesting activities, Boahen and colleagues (2007) found that CA required 48 work days per growing season, compared to 83 days required by slash-and-burn agriculture. The greatest labor savings in CA were those associated with weeding and the collection and burning of slash.

Sustained and stable food production generated by CA systems can significantly improve the nutritional status of vulnerable households and communities, thus reducing susceptibility to disease and other threats and increasing the availability of productive farm labor. These benefits are especially important for households affected by HIV/AIDS, malaria, hunger, war and conflict, or migration. For example, in the Laikipia District in Kenya, households affected by HIV/AIDS benefited from reduced labor needs and increased nutrition following CA adoption (Kaumbutho and Kienzle, 2007). Similarly, CA helped affected households in Siaya District, where HIV/AIDS prevalence is over 38% and family members spend significant time caring for the ill. In southern Sudan, returnees from war found CA to be an attractive option because of its reduced labor requirements (Apina, 2009). CA not only tends to reduce labor in the long-term; it also results in a more even distribution of labor throughout the production cycle. As these examples illustrate, CA can increase labor supply (through better health) while reducing demand, thus creating a labor situation that is much more manageable for rural households and communities.

Gender Dimensions

The human effects of CA are not always gender-neutral in terms of labor requirements, empowerment, or economic benefits and costs. There has not been a large amount of published research that disaggregates labor effects of CA by gender, but based on available information, CA can either increase or decrease the total time that women spend on agriculture. For example, CA reduces or eliminates plowing, which is traditionally done by men, but may increase labor requirements for women associated with land preparation (e.g., digging of planting basins) and weeding. These increased labor requirements may discourage women from adopting CA, even when labor requirements decrease in the long-term (Silisi, 2010).

In other contexts, CA may preferentially benefit women. In Ghana, for instance, the most time-consuming activities in conventional slash-and-burn agriculture are uprooting grass and de-stumping. As these tasks are mostly done by women and children, a transition to CA was found to increase the time available for other household activities (Boahen et al., 2007). Similarly, in Zambia, a switch to CA allowed women and children to carry out lighter and more diversified tasks (Baudron et al., 2007). For female-headed households that have little or no access to plows or plowing services, CA may be a more feasible option since land can be prepared through ripping, and seeding can be accomplished with jab planters, which are portable and easy for women to operate (Shetto and Owenya, 2007; Kaumbutho and Kienzle, 2007).

Where CA reduces the overall time required for farming, it may allow women to diversify their activities by participating in off-farm income-generating activities (Baudron et al., 2007; FAO 2010d). Because of rural-urban migration and HIV/AIDS, there is a dearth of young males and a high proportion of female-headed households and throughout much of rural Africa. Lower labor requirements can be a significant advantage for women who are both farmers and caretakers. Reduced work hours, less heavy farm work, and lower stress associated with CA are all valued highly by women (Baudron et al., 2007).

In Africa, women often play a central role in the decision to adopt CA, in part because they tend to be more actively involved in small-scale farming than men. In Malawi, the CA adoption rate for women was found to be 14% higher than the rate for men (Mloza-Banda and Nanthmabwe, 2010), emphasizing women's important role in agricultural innovation. Because of their year-round presence in villages, women may engage more actively than men in farmers' groups or other social structures (e.g., seed saving groups, village savings and loan groups, etc.) that help households adopt CA and reap its benefits. Investment in CA may also provide opportunities for increased attention to gender issues in agriculture. For example, CA practices may encourage more consultation within the family on resource use and greater acceptance of women as leaders (Kaumbutho and Kienzle, 2007).

Despite these opportunities, in many parts of Africa there remain significant barriers to CA adoption by women, stemming from customary gender roles. For instance, women in Africa often have less access than men to resources such as land, inputs, credit, education, and extension services—all of which may be important to support transitions to CA (Silisi, 2010). For these reasons, CA investment programs should explicitly consider gender dimensions and, when necessary, provide incentives and participatory education and training oriented specifically to women.

Land ownership systems may present more entrenched barriers to female-led CA adoption. Land tenure systems in parts of Kenya, for example, require women that want to adopt CA to obtain permission from male relatives (Kaumbutho and Kienzle, 2007). In Lesotho, women who make improvements to land that they farm but are not allowed to own risk losing their fields to male relatives (Silisi, 2010). Perversely, by making fields more productive through the investment of labor and inputs as part of CA, women may increase the value of these fields and the risk of losing their land. In parts of Ghana, women have access to less agricultural land than men, and may thus be less willing or able to experiment with new farming techniques whose outcomes are unknown (Boahen et al., 2007).

Biodiversity and Ecosystem Services

Conservation agriculture tends to have three broad categories of impacts on the conservation of biodiversity and ecosystem services, all of which are generally positive. First, CA has direct impacts on plot- and farm-scale ecosystem services, which are deliberately managed as part of CA practice. Second, CA has indirect effects on additional ecosystem services as well as associated biodiversity within and around cultivated areas at the farm and community scale. Third, CA has indirect effects on biodiversity and ecosystem conservation at the community, landscape, and even larger scales.

An integral part of CA is the management of soil fertility and hydrological cycling, two key ecosystem services that support agricultural productivity. Considerable research has been conducted on these potential benefits in sub-Saharan Africa and elsewhere. In terms of soil fertility, the improved soil structure resulting from CA enhances aeration and other conditions required for efficient nutrient cycling. Soil organic matter has been found to increase significantly over time in CA systems, due primarily to the introduction of additional organic matter as crop residues or mulch and to the reduction or elimination of tillage, which tends to speed the oxidation of soil organic matter (Hobbs et al., 2008; Kassam et al., 2009). Zero tillage systems are also associated with increased levels of available phosphorus in the upper soil layer (e.g., 0-5 cm), apparently due largely to the role of biological processes in phosphorus cycling (Verhulst et al., 2010).

The evidence regarding the effects of CA on nitrogen availability is somewhat mixed. Nitrogen availability may be lower due to initial immobilization caused by crop residues on the surface (Giller et al., 2009; Verhulst et al., 2010) and higher leaching of inorganic nitrogen (Reicosky and Saxton, 2007). Thus, nitrogen fertilizers may be desirable in young CA systems. Over time, however, the need for fertilizer inputs is generally reduced. In established CA systems, most nutrients are concentrated and maintained in the top 10 cm of the soil, where they are readily accessible to plants (Kassam et al., 2009). Soil fertility also benefits from reduced rates of erosion in CA systems (Reicosky and Saxton, 2007).

CA has also been found to have beneficial effects on water management and water use efficiency. With an increase in soil organic matter and root density under CA, water infiltration and water holding capacity are improved, making water more available throughout the farming cycle (Reicosky and Saxton, 2007). For each percent increase in soil organic matter, an additional 150 m^3/ha of water can be stored in the soil (Friedrich, 2008). Surface mulches and improved soil pore structure also increase infiltration and absorption capacity, while reducing evaporation. These benefits help reduce the risk of erosion and flooding during heavy rains, contribute to aquifer recharge, and make more water available to crops (Hobbs, 2007; Derpsch, 2008; Verhulst et al., 2010). Taken together, these characteristics increase crops' resistance to drought and tend to reduce yield variations between dry and wet years relate to conventional farming practice.

The indirect effects of CA on other ecosystem services in agricultural landscapes have not been well-studied. There is a theoretical basis and limited empirical evidence to support the notion that CA can help maintain and restore groundwater tables by increasing surface water infiltration. However, there is not sufficient research to confirm this relationship as being broadly true. Diversification of agricultural landscapes through the use of crop rotations, cover crops, intercropping, agroforestry, and rotational fallows is likely to increase ecosystem services provided by non-domesticated species (insects, birds, bats, etc.), including pollination and pest control. These relationships have not been specifically studied in relation to CA management. However, based on research elsewhere in Africa, Europe, and the Americas, it is reasonable to hypothesize that increased landscape diversity would almost always improve pollination services, and frequently, but not always, help protect crops from pests and predators.

The indirect effect of CA on broader biodiversity and ecosystem conservation is of particular interest to the CARE-WWF Alliance. From a conservation standpoint, CA has the potential to increase the habitat value of agricultural mosaics by increasing vegetation diversity and connectivity through the establishment of agroforestry plots, fallows, woodlots, and other vegetation elements. In addition, CA has the potential to increase the sustainability and productivity of existing agricultural plots and rural communities, thus reducing pressure to establish new plots in areas of natural habitat. Prosperous, self-contained agricultural villages may also be less subject to human-wildlife conflict (e.g., elephants raiding crops or predators feeding on livestock) and easier to defend against such adverse wildlife interactions than more dispersed farms and settlements within a natural habitat matrix (M. Wright, WWF, pers. comm.).

However, experience from decades of integrated conservation and development projects suggests that this sort of conservation benefit will not occur automatically because the desired conservation outcome (e.g., reduced incursions into natural habitat) is not directly or conditionally linked to the development interventions (e.g., conservation agriculture) (Ferraro 2001). In the Zambia's Luwanga Valley, for instance, the COMACO (Community Markets for Conservation) project supported by the Wildlife Conservation Society is trying to protect forests and wildlife by promoting CA and other strategies for improving the viability of sedentary agriculture. Yet, cultural traditions in the valley encourage farmers to control as much land as possible, as this is perceived to be related to an individual's wealth. Thus, even where farmers have adopted CA, they have also tended to maintain other plots in conventional agriculture, and to continue expanding agricultural operations into new land areas (L. Gatere, Cornell University, pers. comm.). While the CA portion of the project has benefitted many thousands of small farmers, it has not compelling demonstrated a reduction of pressure on nearby forest habitat. By contrast, the component of the COMACO project that assists farmers with livelihood alternatives in exchange for relinquishing their metal wildlife snares (i.e., a direct and condition link between livelihood investments and conservation outcomes) has effectively reduced wildlife poaching in some areas. Thus, while CA does have the potential to support biodiversity and ecosystem conservation beyond farms and farm communities, such relationships must be deliberately planned and managed within projects, ideally through direct mechanisms that are based on the salient household and community decision-making factors.

Principal Constraints and Opportunities for CA in Africa

This section summarizes the major constraints and opportunities for the adoption and scaling-up of CA in sub-Saharan Africa. At a generic level, key constraints to CA adoption in Africa are well-known, and include biophysical constraints (e.g., climate), knowledge constraints, input constraints, financial constraints, and structural constraints (e.g., government policy, investment priorities, and land tenure systems), in addition to the constraints related to labor and gender dynamics are discussed above. It is difficult to generalize about the relative importance of these different constraints because such data have not been standardized across diverse settings (Baudron et al., 2007). To understand how these constraints interact and influence decision-making in specific contexts, it is helpful to read some of the excellent case studies of African CA that have been prepared by ACT, FAO, and others in the past few years. Several of these examples are summarized in Table A2-1 (in Appendix 2).

Agroecological and Climatic Suitability

CA is applicable across diverse geographic regions, agroecological zones, soil types, plot sizes, and crops throughout Africa (Derpsch et al., 2010; FAO, 2010a). Thiombiano and Meshack (2009) examined the biophysical conditions—particularly related to the availability of water and biomass—that would allow for CA in different parts of Africa. Sub-humid zones were found to have the best potential for CA, and deserts were the only type of ecosystem not suitable for CA due to insufficient biomass production. In arid and semi-arid zones, reduced tillage and direct seeding are needed to minimize water loss, promote timely planting, and make use of scarce rainfall.

Studies by the Regional Land Management Unit (RELMA, 2007) found that in conditions of limited water availability CA should focus on water harvesting and water use efficiency. In these settings, less emphasis should be placed on soil cover maintenance, and fertilizers should be used to counteract soil nutrient depletion. Increases in biomass production over time can lead to greater soil cover, allowing for more organic matter and improved water holding capacity in soils. In semi-arid zones, options for cover crops and crop residues for soil cover increase with higher humidity levels. Cover crops are a useful starting point in sub-humid zones as well, and can result in better mulch, higher yields, and reduced weed pressure. Agroforestry systems, such as ICRAF's Evergreen Agriculture, are examples of systems that add soil cover in semi-arid and arid environments.

Knowledge Constraints

Adopting CA requires substantial changes not only in practices, but also in mindset (Derpsch, 2008b). CA contradicts much of conventional farming knowledge and farming traditions. Many farmers are accustomed to thinking of the plow or the hoe as an essential part of agriculture, and may find it difficult to overcome the idea that plowing is not required for successful planting. It can be particularly difficult to convince farmers to adopt CA if they do not experience strong environmental or economic pressures to change. Conventional agricultural practices may also be tightly woven into local culture and ritual, making such practices even more entrenched.

While farmers that practice CA tend to have a positive view of it (Friedrich and Kassam, 2009), a lack of experiential knowledge hinders adoption. As with agriculture in general, CA is a knowledge intensive process that requires substantial planning, intuition, and a willingness to experiment and learn. However, the knowledge base for CA is substantially different from that for conventional agriculture. For instance, the recommended approaches to remedying soil compaction differ considerably between conventional agriculture and CA, as do methods for seeding, fertilization, erosion control, residue management, and water management. When reliable information on CA is not available from formal support systems (e.g., extension agents or NGOs), neighbors, or prior experience, farmers may not be able or willing to adopt CA fully or optimally from the start, which can lead to disappointing results and subsequent dis-adoption.

Knowledge of CA remains low across most of Africa, and the approach is rarely taught, even at agricultural universities. Although some countries have incorporated CA into their extension programs, others actively promote conventional farming techniques that are at odds with CA. Even where CA is taught, this education is often not well integrated with land management systems at the local level. For instance, CA may be demonstrated in plots at experiment stations, but not in farmers' fields where it is more likely to lead to smallholder adoption (Baudron et al., 2009). Successful CA extension models have been demonstrated in several countries (e.g. farmer field schools in Uganda; Nyende et al., 2007), but, with a few exceptions, have not been brought to scale.

Input Constraints

Access to equipment, seeds, fertilizers, and herbicides is a significant constraint to scaling up CA in Africa. CA does not necessarily require more equipment than conventional agriculture, but some of the equipment is different and is not always available. The most significant differences tend to be in land preparation and seeding. In silty or clayey soils, the soil surface is penetrated only in precisely-targeted lines or pits that will be seeded. Seeds are then deposited into these areas or inserted directly into the ground through the mulch or ground cover layer. Some conventional agriculture tools can also be used for CA (e.g., certain weeding tools), while other can be modified for CA (e.g., hand hoes can be made narrower to dig CA planting basins or rows). For non-mechanized CA involving simple hand tools, equipment costs are relatively low (if the requisite equipment is available at all). Costs increase significantly when using animal- or tractor-powered implements (IIRR, 2005).

Limited access to (or affordability of) inorganic fertilizers, pesticides, and herbicides may also represent a constraint to practicing CA in a maximally productive manner. However, one of the chief advantages of CA is that it can increase yields in contexts where agrochemicals are not available or not affordable, by fostering biological processes and management practices that enhance soil fertility, pest control, and weed control. Nitrogen-fixing plants are an integral part of most CA systems, and can include shrubs, annual herbaceous plants, or trees such as *Faidherbia albida*. Intercropping with these species improves yields, soil health, and soil chemical and biological properties while reducing weed and pest problems (Akinnifesi et al., 2010). Despite these benefits, however, spontaneous adoption of cover crops for soil fertility enhancement alone is uncommon; rather, the plants must offer some direct benefit, such as human food or animal fodder (Baudron et al., 2009).

Access to high-quality seeds is a constraint to CA, as it is for conventional agriculture, in much of Africa. However, CA also requires seeds for cover crops or intercrops, which may be more difficult to obtain if they are species that have not traditionally been grown locally.

A final input constraint that tends to be more severe in CA than in conventional agriculture is the availability of biomass for mulches or organic fertilizer. Although soil nutrients and soil cover in CA can often be provided mainly by cover crops or intercrops, some exogenous organic matter may be needed to provide supplemental fertilizer and soil cover. Non-edible biomass in farm fields and the surrounding field margins, fallows, and forests is often in high demand for livestock fodder, firewood, building material, and other uses. CA places an additional demand on these resources. In places where the population density is relatively low or rainfall is moderate to high, biomass is rarely a major constraint. However, this constraint can become severe in semi-arid regions with high population density.

Not surprisingly, CA adoption rates tend to be highest when donor-funded projects provide the necessary machinery and inputs free or at a low cost. However, unless efficient and reliable input supply chains are also established, input constraints will persist after a project ends, threatening to undermine any gains.

Financial Constraints

As discussed in the previous section, CA is generally more profitable in the long-term than conventional farming. However, achieving these long-term benefits may require initial investment, which is often prohibitively expensive or risky for small farmers to undertake on their own. Vulnerable farmers are especially risk averse due to household food security concerns, and there is little room for error.

In addition, while many farmers reap benefits in the first year of practicing CA, others do not realize increased yields or profitability for 3-7 years (Hobbs, 2007). During this time, farmers sometimes choose to abandon CA; thus, long-term adoption is more likely when CA provides significant benefits in the first or second year (Reij et al., 2009). Such immediate benefit is more likely when CA is promoted in conjunction with good agronomic practices, improved seeds, and sometimes inorganic fertilizers (see Box 1).

Several approaches have been used to overcome the dual financial constraints of the initial investment required for CA and the potential for negative returns for a period of up to several years. Donor-funded projects can address both of these constraints by providing free or low-cost inputs, extending credit to farmers (through direct loans or establishment of community financing operations), and educating farmers about the benefits of CA and ways to improve its profitability. Other rural finance mechanisms can also help farmers overcome the short-term investment hurdle to achieve CA systems that are more profitable and sustainable in the longer term. Commercial banks and even microfinance institutions are effectively absent throughout much of rural Africa. However, a variety of community savings and lending models have been implemented successfully throughout the continent. These include rotating savings and credit associations and village savings and loan groups. The latter has been adopted widely within CARE projects in Africa. These groups pool household resources and agricultural profits to create a structured collective mechanism for saving, short-term lending, and investment in household economic activity. With or without these various forms of financial support, farmers often hedge financial risks by adopting CA piecemeal, or on a fraction of their farm. Doing so reduces short-term expenditures and allows the farmer to guard against the possibility that yields will drop before they rise. Piecemeal adoption is a logical strategy at the household level, but makes it difficult institutionalize CA rapidly over large areas.

Policy, Investment, and Land Tenure Constraints

Structural constraints to CA include unsupportive policy environments, extension and education systems, incentive structures, donor investment priorities, and land tenure systems. Conventional farming methods are deeply entrenched in many African countries, from the local level (where the farming cycle is commonly embedded in village tradition and ritual) to the national level (where research, education, and training rarely have a strong CA component). Even in countries where many farmers are practicing CA, there is often little awareness of CA among policy makers, and in some cases existing policies work against CA (Thiombiano & Meshack, 2009).

Investment in CA in Africa has been very limited to date, but there are some promising signs that this could change. After a dramatic decline in funding for agricultural development in Africa from both domestic sources and foreign aid from the 1980s until very recently, the past few years have witnessed renewed commitments to increase food production in Africa, both from donors and from many African leaders. For instance, under the Comprehensive Africa Agriculture Development Program (CAADP) of the New Partnership for Africa's Development, several African governments have committed to allocating at least 10% of national budgets to agriculture. Key donor-funded initiatives for African food security (e.g., the United States' Feed the Future initiative and the Alliance for a Green Revolution in Africa) are focusing on Green Revolution strategies to a significant degree, but also provide opportunities for supporting CA. For instance, AGRA states on its website that it seeks to "promote conservation agriculture in all production systems" through an Integrated Soil Fertility Management approach to "make the best possible use of fertilizer and organic inputs" (AGRA, 2010). Under CAADP's Land and Water Management pillar, conservation agriculture has been promoted specifically through a Norwegian-funded initiative in southern Africa. The much larger TerrAfrica Initiative has helped leverage funding for sustainable land management (which sometimes includes CA) through the Global Environment Facility. In addition, important international organizations such as FAO and the International Fund for Agricultural Development have begun promoting CA in some of their programming.

In practice, CA is almost always promoted through a project approach. However, the short timeframe typical of agricultural development projects is at odds with the type of longer-term engagement that is usually needed to institutionalize CA and adapt it to the local context (FAO, 2008). Without ongoing support from government policies, extension services, and market infrastructure, among other elements, pilot projects become difficult to sustain or expand, and the benefits of CA remain limited.

CA can be adopted within either statutory or customary land tenure systems. Customary tenure systems are typical in the small farmer-dominated rural areas of most African nations (ECA, 2003). These tenure systems often combine individual and communal rights within a framework defined by written or unwritten customs and governed by decision-making authorities at the family, clan, chief, or village level. Given that customary tenure systems vary widely, it is helpful to identify some of the characteristics of these systems that can impinge on the viability and effectiveness of CA. These factors include:

Duration and security of individual rights to land: CA represents a long-term investment in the fertility and sustainability of a farm plot. Clear, long-term individual (or household) rights to the land can encourage such long-term investment, while the absence of such rights may discourage it (Boahen et al., 2007; FAO, 2010c).

Governance and decision-making for communal plots: Since farming communities tend to be risk averse, where land is communally owned, there may be social pressure to use well-tested conventional practices as opposed to practices that are unfamiliar or perceived to be risky, such as CA.

Effects of shared grazing rights: In many customary tenure systems, farmers possess individual rights to manage their fields during the planting season, but these fields revert to communal spaces available for livestock grazing during the dry season. Such arrangements pose a major challenge to farmers that wish to conserve crop residues or other biomass for CA. In principle, it is possible to modify systems of communal grazing rights to allow farmers to exclude livestock and retain biomass in their fields, but doing so tends to be politically challenging and there are few documented instances of this occurring. The issue of livestock grazing is discussed further in the section of this report on "Question 5: Synergies and Tradeoffs among Multiple Objectives."

Conceptions of ownership based on active use: In many customary tenure systems, use rights are claimed and retained through individuals' active use of land. Planting of annual crops demonstrates active use, whereas long fallows or natural regeneration, even if done deliberately, may be perceived as the discontinuation of active use. The perceived lack of active use may make the plot subject to claims by other potential users. Perennial systems including agroforestry may help individual retain use rights without needing to plant annual crops each season.

Customary tenure as mechanism for adaptation: Although land tenure arrangements that are ambiguous, informal, or overlapping can inhibit individual investment in sustainable soil and water management (including CA), such arrangements may also function as a safety net or adaptation mechanism by allowing land resources to be re-allocated quickly in the event of changing circumstances, including natural disasters. This flexibility may be especially important for the most vulnerable members of a community. While customary tenure systems do not always provide such adaptation benefits, this issue highlights the value of assessing tenure systems in a comprehensive and nuanced way before recommending changes to 'improve' existing arrangements as part of an agriculture or rural development project.

Results: Assessing Existing CA Practice and Approaches

This chapter devotes one section each to research questions 1, 2, 4, and 5, which focus on assessments of existing CA practices. Questions 3 and 6—which pertain to opportunities for future project, program, and policy changes—are addressed in the next chapter.

Question 1: CA and Climate Adaptation

This section addresses the question: “Are CA projects significantly increasing farmers’ ability to adapt to current climate variability and future climate change?” To do so, it develops a framework for evaluating the effect of CA on the adaptability of smallholder farming systems to climate change.

In the past few years, climate change adaption has been widely discussed and promoted as an important goal for all human systems, particularly agriculture. Recent projections suggest that climate change could significantly reduce crop yields and increase yield variability in many regions of the world within a decade or two, including 20-35% decreases in maize yields in southern Africa by 2030 (Lobell et al., 2008). However, through advance preparation and careful management of agricultural systems, these risks could be substantially reduced. Deliberate action is thus essential to minimize disruptions to the food supply by establishing agroecosystems, institutions, and knowledge systems that can respond nimbly to changing circumstances.

Box 3. Key Terms and Concepts Related to Climate Change Adaptation

“Adaptability,” “resilience,” and the related term “resistance” are three different descriptors of how a system responds to change. Resistance is the tendency of a system to remain stable in the face of external perturbations. For instance, an agroforest that continues to produce similar yields despite fluctuating rainfall levels would be considered highly resistant. Resilience refers to the system’s ability to recover quickly from damage or change—for example, a hurricane or pest outbreak. While this term has its roots in ecology, its use has now broadened to include the concept of “socio-ecological resilience” (Folke, 2006), which encompasses the role of humans in adaptively managing systems to maintain them within a range of bounds that are conducive to human wellbeing (e.g., maintaining minimum crop yields, water availability, or profitability). This latter meaning is quite similar to the term “adaptability,” which refers to the capacity of human actors to effect system resilience. Characteristics of adaptive systems include high levels of capacity for learning, experimentation, and cooperative action. Adaptability implies the use of long-term planning and strategic action to address change both before and after it occurs. By comparison, “coping” is a reactionary response to unanticipated change, often conducted in a crisis mode and oriented toward short-term survival (CARE, 2009a).

A vulnerable system is one that has little resistance, resilience, or adaptability to external perturbations. The Intergovernmental Panel on Climate Change defines vulnerability to climate change as “[t]he degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.”

Over the past few years, several helpful frameworks have been developed for evaluating the adaptability of rural communities to climate change. Appendix 3 presents and discusses a few of the frameworks that are most relevant for assessing CA and its linkage to the sustainability of rural livelihoods at multiple temporal scales and spatial levels (household, village, etc.). However, none of the existing frameworks are designed specifically to assess the climate change adaptation benefits of CA. Accordingly, this study provides a framework tool for evaluating the effects of CA, as broadly defined, on climate change adaptation (see Table A3-1 in Appendix 3).

As indicated by this framework, all CA systems tend to provide at least some climate change adaptation benefits relative to conventional farming systems—particularly related to soil fertility and water conservation and use. The framework also recognizes, as noted earlier in this report, that some of the most important adaptation benefits of CA projects and programs arise not from site-scale agronomic practices but from associated investments to improve local knowledge, capacity, social capital, market access, seeds, and financial services. This notion of contextualizing CA within a broader development program is consistent with CARE's approach to community-based adaptation. Under this approach, CA techniques are used as part of a comprehensive strategy for improving the sustainability and resilience of livelihoods within target communities.

Question 2: CA Impacts on Greenhouse Gas Balances

This section explores the extent to which current CA projects are reducing greenhouse gas (GHG) emissions or sequestering significant net amounts of carbon. To do so, it reviews evidence from the published literature on the contribution of different agroecosystem components to GHG mitigation. It then evaluates the practice of CA in sub-Saharan Africa in light of these data.

According to the Intergovernmental Panel on Climate Change (IPCC), agriculture, deforestation, and land-use change together account for about 31% of total global anthropogenic GHG emissions. In Africa, land use change is a disproportionately important contributor to GHG emissions, accounting for 48% of the continent's emissions from 2000-2005 (Canadell et al., 2009). Put another way, Africa accounted for just 2.5% of the world's CO_2 emissions from fossil fuel combustion, but 17% of all global CO_2 emissions from land use change. At the same time, carbon in African topsoils is being released to the atmosphere as the many of the continent's croplands, rangelands, and forests become progressively more degraded (Shames and Scherr, forthcoming). Looking to the future, Africa is projected to have the highest growth in agricultural GHG emissions, alongside the Middle East, largely due to agricultural intensification and expansion (Smith et al., 2007).

Just as agriculture and land use change has significant potential to exacerbate GHG emissions and climate change, it also holds major potential to mitigate these impacts. Worldwide, the "technical" mitigation potential from agriculture (i.e., the biophysical capacity to mitigate GHG emissions) is estimated to be 5,500-6,000 million tons of CO_2-equivalent per year (Mt CO_2-eq/yr) by 2030 (Smith et al., 2007). The economically feasible mitigation potentials are estimated to be 1,500-1,600, 2,500-2,700, and 4,000-4,300 Mt CO_2-eq/yr at carbon prices of \$20, \$50 and \$100/tCO_2-eq, respectively. About 70% of this mitigation potential lies in developing countries. Sub-Saharan Africa's mitigation potential from agriculture is relatively high, at about 924 Mt CO_2-eq/yr by 2030, compared to 707 Mt CO_2-eq/yr for all of South America and 374 Mt CO_2-eq/yr for North America (Smith et al., 2007).

Within agricultural systems, there are several options for mitigating climate change, including both the reduction of existing or potential emissions and the net sequestration of CO_2 to offset emissions elsewhere. The greatest potential mitigation opportunities include:

- **reduction in CO_2 emissions** associated with a wide variety of practices, including deforestation for agriculture and oxidation of soil carbon;
- **net sequestration of CO_2 in agroecosystems**, including in soils and trees;

- **reduction in methane (CH_4) emissions**, which are mostly associated with livestock raising, manure management, and paddy rice production; and
- **reduction in nitrous oxide (N_2O) emissions**, which are associated with nitrogen cycling and microbial activity in soils of all types.

According to the IPCC, soil carbon sequestration offers by far the most important potential for agricultural GHG mitigation, with an estimated 89% of the total technical potential worldwide (Smith et al., 2007). Mitigation of CH_4 emissions and N_2O emissions from soils account for 9% and 2%, respectively, of the total mitigation potential (with all three gases normalized to units of CO_2-eq). These estimates, however, do not include the potential for carbon sequestration or emissions reductions in trees and other aboveground biomass in agricultural landscapes and rural land-use mosaics. With these components added, total mitigation potential from agricultural landscapes remains much larger for CO_2 than for CH_4 or N_2O. However, CH_4 is quite important in certain agricultural sectors or components (especially livestock and rice production), while N_2O is a contributing GHG variable in all agricultural sectors, although its dynamics are less well understood.

Table 3 synthesizes generalized data (worldwide and for Africa) on the mitigation potential of various categories of agricultural practices. Under the heading “Mitigating effects,” the signs indicate whether the practice results in net GHG mitigation (+), net GHG emissions (-), or possibly either, depending on the context (+/-). Under the heading “Data Confidence,” information is provided on the level of agreement and evidence among peer-reviewed studies for each practice. The next pair of columns provides estimates of the mean total mitigation (or emission) potential of several of the practices. These estimates include the effects of CO_2, CH_4, and N_2O, which are all standardized and added into the single measure of tCO_2-eq. The values listed indicate low/**medium**/high estimates. Finally, the right-most column indicates the total mitigation potential of each category of practice Africa-wide by the year 2030.

Several relevant conclusions can be drawn from this table. First, understanding of CO_2 stocks and fluxes is greater than that for CH_4 and especially for N_2O. Second, cropland, grazing management, and organic (wetland) soil management all offer roughly equal mitigation potential for Africa by the year 2030. Third, at the plot level, there is considerable variability and uncertainty in the mitigation potential offered by key practices including agronomy, nutrient management, tillage and residue management, and agroforestry. Finally, the potential for GHG mitigation is about twice as large in warm-moist climates as in warm-dry climates. However, this finding is generalized worldwide and thus should not be over-interpreted for specific African environments.

Table 3. Synthesis of data on generalized (global and Africa-wide) impacts of agricultural management practices on GHG fluxes. See the text for discussion. Data source: Smith et al., 2007.

Category	Sub-category	Mitigating Effects			Data Confidence		Mean mitigation potentials globally (tCO_2-eq/ha/yr)		Total mitigation potential in Africa by 2030 (Mt CO_2-eq/yr at \$20/t CO_2-eq)
		CO_2	CH_4	N_2O	Agreement	Evidence	Warm-dry climate	Warm-moist climate	
Cropland management	Agronomy	+		+/-	High	Med	0.1/**<u>0.3</u>**/0.5	0.5/**<u>0.9</u>**/1.3	
	Nutrient management	+		+	High	Med	0.2/**<u>0.3</u>**/0.7	0.0/**<u>0.6</u>**/1.1	
	Tillage/residue management	+		+/-	Med	Med	-0.7/**<u>0.3</u>**/1.4	-0.4/**<u>0.7</u>**/1.8	
	Water management (irrigation and drainage)	+/-		+	Low	Low			
	Rice management	+/-	+	+/-	Med	Med			
	Agroforestry	+		+/-	High	Low	-0.7/**<u>0.3</u>**/1.4	-0.4/**<u>0.7</u>**/1.8	
	Set-aside, land-use change	+	+	+	High	High			
	Total								69
Grazing land management and pasture improvement	Grazing intensity	+/-	+/-	+/-	Low	Low			
	Increased productivity (e.g., fertilization)	+		+/-	Med	Low			
	Nutrient management	+		+/-	Med	Med			
	Fire management	+	+	+/-	Low	Low			
	Species introduction	+		+/-	Low	Med			
	Total								65
Management of organic soils	Avoiding drainage of wetlands	+	-	+/-	Med	Med			61
Restoration of degraded lands	Erosion control, organic amendments	+		+/-	High	Med			33

Review of Evidence on CA, GHG Emissions, and Carbon Sequestration

Similar to agriculture in general, CA can help mitigate atmospheric GHG by: 1) reducing existing emissions sources, and 2) sequestering net carbon. Baker and colleagues (2007) estimate that the conversion of all croplands to conservation tillage globally could sequester 25 Gt C over the next 50 years. This is equivalent to 1,833 Mt CO_2-eq/yr, making conservation tillage among the most significant opportunities from all sectors (not just agriculture) for stabilizing global GHG concentrations.

Scaling down these global estimates to the continental, landscape, or plot scale to estimate the mitigation potential of CA in sub-Saharan Africa entails considerable challenges. Overall there is insufficient information on the GHG impacts of CA practices, especially for developing countries in the tropics and sub-tropics (Govaerts et al., 2009). Although many studies have examined GHG stocks and fluxes associated with CA systems and various CA practices, these data span a wide range of geographies, climates, and agroecological zones, and are generally not comparable or amenable to meta-analysis (Nair et al., 2009). For some types of CA systems and practices in some geographies, we can be reasonably certain about the direction (positive or negative) and order of magnitude of GHG impacts; for others systems and practices, even this level of confidence is not yet possible.

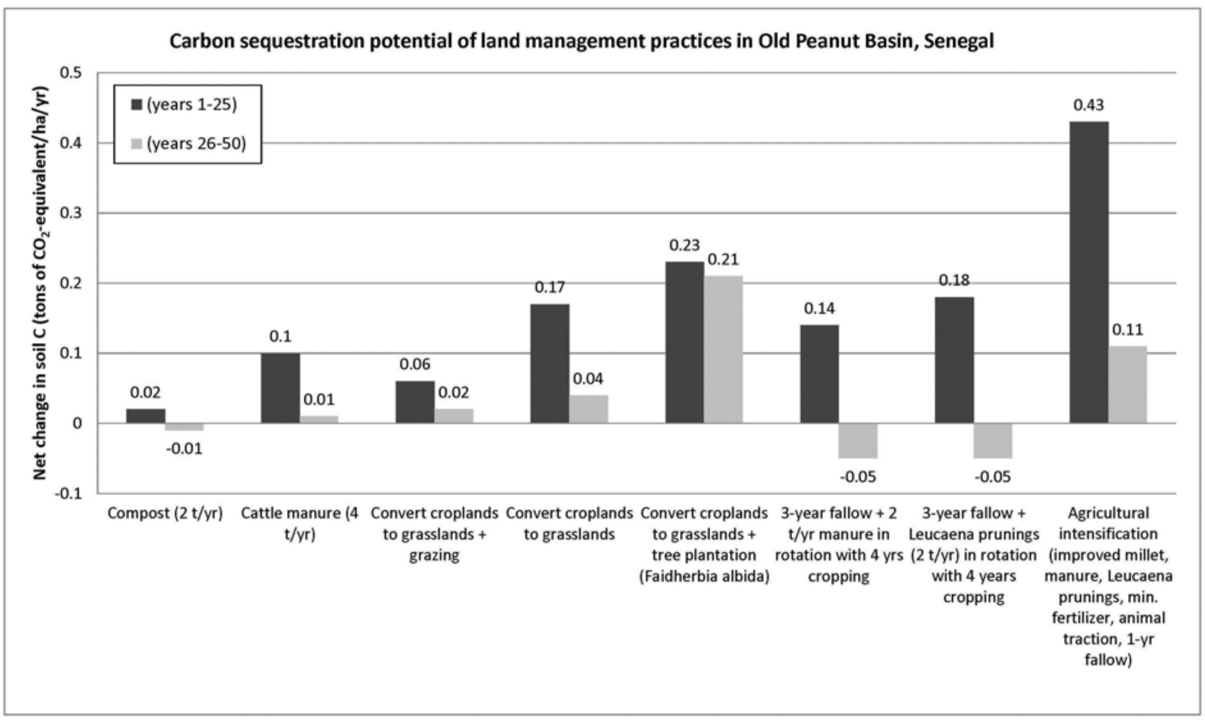

Figure 4. Soil carbon sequestration potential (in tons of CO_2-eq/ha/yr) of different combinations of agricultural practices that may be used in CA. The graph reports results from the CENTURY model of agricultural yield, soil, and carbon dynamics, run for the Old Peanut Basin of Senegal, a semi-arid region (350-700 mm of annual rainfall) in which major crops include millet, groundnuts, sorghum, and cowpea. Figure is drawn from data presented in FAO, 2004.

Despite these challenges, it is helpful to provide some broad estimates—however rough—of the magnitude of the C sequestration potential of CA practices to understand the degree to which C finance is likely to be a feasible component of CA projects. Table A4-1 (in Appendix 4) presents illustrative data from about 40 studies on the GHG emissions reduction and belowground and/or aboveground carbon sequestration benefits of various agricultural and landscape management practices that might be associated with CA. Most of these studies report results for African land-use systems. Figure 4 compares the estimated soil C sequestration potential of alternative plot-scale management strategies (including some CA approaches) practiced in a single location (the Old Peanut Basin in Senegal), based on modeling results. This figure also indicates the way in which the incremental net carbon sequestration benefits of sustainable agriculture practices might diminish over a period of decades as agroecosystem components begin to become carbon-saturated and approach an equilibrium state. Figure 5 is a visual heuristic for comparing the order-of-magnitude C sequestration potential of various CA components, including both site and landscape management practices and both belowground and aboveground carbon pools. It is important to note that since the ranges of recorded GHG mitigation values for many of these practices is quite wide, the relative size of these mitigation benefits could shift considerably in specific situations.

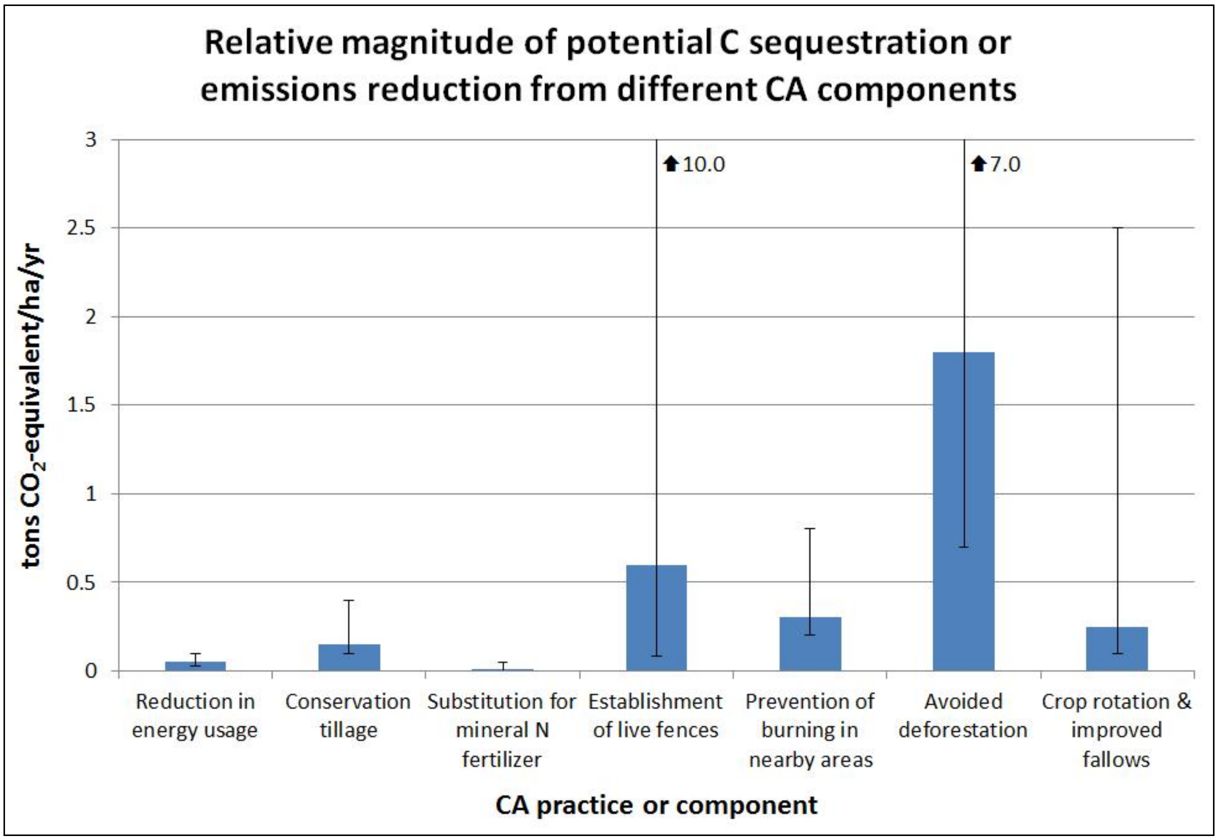

Figure 5. Order-of-magnitude ranges for the relative carbon sequestration potential of different components of a CA system (as broadly defined to include plot, farm, and landscape scale practices). The range of values indicated by the error bars are based on data from the literature reviewed for this study; actual ranges may be even wider. The relative size of bars on this graph are mid-range estimates based on a synthesis of the literature on the GHG mitigation potential of each practice in semi-arid to semi-humid environments in sub-Saharan Africa. The data for avoided deforestation assume that CA provides a sustainable system for sedentary agriculture, thus eliminating slash-and-burn agriculture and the conversion of native ecosystems to farm fields. Values for avoided deforestation are per year, averaged over a 50 year analysis period. While this diagram is highly generalized, it does provide a first-order approximation of the relative sizes of the GHG mitigation benefits that might be attained from different CA practices.

Monitoring, Reporting, and Verification

GHG fluxes from agriculture, forestry, and land use change tend to be more complex and difficult to measure than those from other sectors, such as energy, industrial production, or transportation. Accordingly, much effort has recently gone into improving the monitoring, reporting, and verification (MRV) of agricultural greenhouse gases. Reliable MRV is important not only for improved management of such GHG, but also for the inclusion of agriculture, forestry, and land use change within climate regulation frameworks. Credible MRV can help address concerns of some climate protection advocates that GHG emissions reductions or carbon sequestration from agriculture are too uncertain, too context-dependent, or too ephemeral to be considered valid components of a global GHG mitigation strategy.

Until very recently, MRV methodologies for agriculture tended to provide simplified averages, which were not sufficiently accurate for site-specific estimations. Aboveground, the main challenge is accurate estimation of tree biomass, which comprises the major portion of aboveground C stocks in most ecosystems. Historically, remote sensing and modeling generally did not provide the necessary detail required for further computations. Allometric equations are available for converting tree size (e.g., diameter at breast height) to biomass for different species, but this method requires labor-intensive field measurements, especially for mixed-species stands. Belowground measurements are even more challenging, as carbon sequestration rates depend on site-specific biological, climatic, soil, and management factors (Nair et al., 2009). Scientists disagree on the depth to which soil organic carbon (SOC) sampling must be conducted: in the past, often only the top 20-30 cm of soil was sampled to derive estimates of SOC and other properties (Baker et al., 2007). However, several recent studies and reviews seem to agree that much deeper sampling is probably necessary for monitoring soil carbon in CA systems, as CA practices have a tendency to increase SOC in the upper soil strata but decrease it in the lower strata, sometimes resulting in little total net change.

Several recent scientific advancements and initiatives have rapidly improved the state of MRV for GHG fluxes in agriculture and rural landscape mosaics. A number of working groups, consortia, and research programs are focused on improving the reliability of agricultural GHG measurement protocols for all three major greenhouse gases (CO_2, CH_4, and N_2O) in a wide range of agricultural systems and sectors. The Technical Working Group on Agricultural Greenhouse Gases (T-AGG) is now supporting protocol development for soil carbon management and N_2O emissions reduction on cropland, currently focused on the United States, but with interests in expanding internationally (e.g., Olander and Malin, 2010).

In Africa, the newly developed Africa Soil Information Service (AfSIS) is mapping soil properties as well as aboveground land characteristics at almost 10,000 sampling plots continent-wide to define relationships between biophysical context (elevation, climate, hydrology), on-the-ground management practices, and remote sensing imagery. These relationships can then be applied in the future to conduct lower-cost carbon monitoring of large landscape areas. The Carbon Benefits Project, a complementary initiative involving WWF, the World Agroforestry Centre, and Michigan State University, is using remote sensing, ground-based measurement, modeling, and statistical analysis to develop methodologies to monitor carbon stocks and GHG emissions specifically within complex mosaic landscapes that include agriculture, agroforestry, and other land uses. The hope is that tools such as these will dramatically reduce MRV costs for terrestrial carbon while increasing the credibility (and thus value) of such carbon credits, thereby allowing many more small farmers to benefit from carbon finance. Such approaches are beginning to be operationalized by carbon project developers and certifiers/verifiers through pilot carbon finance projects in Africa and elsewhere, as discussed further in the next section.

Question 4: Potential to Generate Marketable, Cost-Effective Carbon Credits

This section addresses the question: "How could CA projects be designed and implemented to generate eligible, cost-effective carbon credits for the voluntary market in an equitable way without compromising the other benefits that these projects can provide?" To do so, we first review the current status of carbon markets worldwide, and in Africa, to define the context within which carbon projects might be developed from CA and other smallholder land management practices. Next, we review lessons learned from other agricultural carbon projects on key issues such as aggregation of offsets from smallholders, cost-competitiveness of CA-based carbon credits, monitoring protocols and costs, verification or certification, buyer demand, and co-benefits. Options for modifying CARE and WWF CA projects to generate marketable carbon credits are provided in the next chapter, in the section focused on Question 3.

Current Status of Carbon Markets Globally, and in Africa

Carbon markets are in a state of rapid evolution. Not only are the prospects for global regulation of greenhouse gases in flux; so, too, are dialogues regarding the feasibility and appropriateness of including agricultural emissions and land uses within any such regulatory framework. At the same time, technologies for reducing emissions, sequestering carbon, and monitoring GHG dynamics in agricultural landscapes are rapidly improving, as discussed above. The view of carbon markets presented here is current as of early 2011.

Carbon markets are the largest environmental market in the world, valued at $144 billion in 2009 (World Bank 2010). This market consists of two parts: the regulated market and the voluntary market. The regulated market is driven by sub-national, national, regional, and global mandates to reduce GHG emissions, including the Kyoto Protocol and the European Union's Emissions Trading Scheme (EU-ETS). While emissions offsetting is permitted under the Kyoto Protocol and EU-ETS, offsets related to terrestrial carbon sequestration are only a small fraction of total offsets. Regulatory markets have instead focused on emissions reductions and offsets from the industrial and energy sectors, in which Africa has little comparative advantage in generating low-cost offsets. The Clean Development Mechanism (CDM) of the Kyoto Protocol does not permit agricultural or soil carbon sequestration projects, but it does permit offsets related to afforestation and reforestation, which can be related to the restoration of degraded agricultural land and, in some cases, to agroforestry. In Africa, a few CDM projects are under investigation related to restoration of degraded agricultural lands, agroforestry, and reduction in sugarcane burning (Shames and Scherr, forthcoming). To date, only one such project has been approved: a farmer-managed natural regeneration project in Ethiopia. Major obstacles to implementation of CDM projects in Africa include the lack of financial and human resources, as well as the complexity of the CDM's governance of terrestrial carbon projects.

Most GHG offsets related to terrestrial carbon in agricultural systems have been transacted in the voluntary carbon markets, which were valued at $728 million in 2008 but declined to $387 million in 2009 due to the global economic recession and wavering interest in the purchase of "pre-compliance" offsets given doubts about the imminence of GHG regulations in the United States and elsewhere (Hamilton et al., 2010). Within the voluntary markets, there is considerably more interest than in the regulatory markets in land-based GHG offset projects. Because such projects have the potential to generate substantial "co-benefits" such as increased food security or provision of other ecosystem services, they have attracted interest both from donors and NGOs interested in pilot-testing new models for conservation and rural development, and from buyers of carbon offsets who care about the broader social and environmental ramifications of their carbon offset purchases. Terrestrial carbon projects as a share of the total voluntary markets ramped up steeply in 2009, to 28% of the total, or about $108 million worldwide. Of this amount, about $12 million was related to agricultural soil management, $15 million was related to livestock, and $4 million was related to agroforestry (Hamilton et al., 2010). However, Africa's contribution to the voluntary carbon markets remained very small, at 2% of the global total, or 900,000 tCO_2-eq, valued at about $8 million. Ninety percent of this volume was related to forest carbon projects (REDD), with the remaining portions associated with agroforestry, afforestation, and reforestation (Hamilton et al., 2010). As discussed further below, there are some projects currently under development that will generate carbon offsets from agricultural soil management in Africa. However, these projects were not yet sufficiently well developed to be included in the inventories compiled by Hamilton and colleagues.

Although voluntary carbon offsets can be transacted in simple bi-lateral deals between a willing buyer and a willing seller, increasingly the voluntary market is moving toward the use of standards to provide increased credibility for buyers and increased accountability from sellers (Hamilton et al., 2009). Supporting these standards are a handful of methodologies (with many more currently under development) for GHG MRV within agricultural landscapes (see Table 4). These voluntary standards and methodologies are serving as important laboratories for demonstrating the design and feasibility of agricultural carbon projects. Market observers predict that the various standards and methodologies will eventually "shake out" into a smaller number of preferred ones, which may eventually serve as a template for the structure of agricultural GHG offsets within future regulated carbon markets.

Within the voluntary markets, there is interest from some buyers in purchasing "premium" carbon credits that also provide social and environmental co-benefits such as reducing poverty and protecting biodiversity. This segment of buyer demand is particularly relevant for agricultural carbon projects involving smallholders, which often provide a range of co-benefits. At least two carbon standards support the development of agricultural carbon projects with co-benefits: Plan Vivo and the Voluntary Carbon Standard (VCS) (see Table 4). The Climate, Community, and Biodiversity Alliance (CCBA) offers an additional module that can be voluntary added on to carbon standards such as the VCS and CDM that sets additional criteria for a project's impacts on climate, community, and biodiversity (CCBA, 2008). CARE is a member of the CCBA and has been involved in the development of this standard.

A recent study by Shames and Scherr (forthcoming) surveyed agricultural carbon projects in Africa and provides many insights into the emergence of this nascent market sector, the range of approaches that are being attempted, and key opportunities and constraints to scaling-up. Nearly all terrestrial carbon projects in Africa with an agricultural component have been initiated in the past five years, and nearly all can be considered to be pilot projects, or in some way experimental. The study surveyed 81 GHG mitigation projects in 24 Africa countries in which farmers are sellers of carbon offsets. Some of the projects were already operational while others were still being planned or developed. The projects included four categories of practices: 1) off-farm land rehabilitation; 2) on-farm tree-planting, agroforestry, or agricultural soil management; 3) REDD; and 4) miscellaneous emission reductions (see Table 5).

Table 4. Frameworks relevant to carbon market transactions involving agriculture and land use in Africa.

Market segment	Entity under which emission reduction, offset, or compliance units are issued	Methodologies for MRV of greenhouse gases in agricultural landscapes	Additional standards for co-benefits
Voluntary	Voluntary Carbon Standard (VCS)	Demonstration of additionality for AFOLU[2] activities Under review: • Adoption of sustainable agricultural land management • Biochar • Afforestation/reforestation of agricultural lands • Several others	Climate, Community, and Biodiversity Alliance (optional)
	Plan Vivo	Developed specifically for each project, to include baseline assessment, management system, monitoring indicators, assessment of leakage and permanence, and other indicators	Plan Vivo includes environmental and social co-benefit requirements
	Several other standards (Gold Standard, Social Carbon, etc.) do not yet apply to agricultural carbon in Africa	N/A	
Regulated	Clean Development Mechanism	Various methodologies, some of which include forest regeneration and certain types of agroforestry	

Table 5. GHG mitigation activities in African carbon projects involving farmers (*n* = 74). Source: Shames and Scherr, forthcoming.

Mitigation activity	**% of projects implementing this activity**	**% of projects implementing solely this activity**
Off-farm land rehabilitation, with benefits to farmers	53	30
On-farm practices, including tree planting, agroforestry, and agricultural soil management	51	28
REDD, with benefits to farmers	16	7
Miscellaneous emission reductions (biodigesters, green charcoal, reducing N_2O emissions from fertilizers)	9	8

[2] AFOLU stands for Agriculture, Forestry, and Other Land Use.

Early agricultural GHG mitigation projects in Africa often involved simple tree planting, but some of the more recent projects are combining aboveground and belowground carbon sequestration through production practices such as agroforestry and conservation agriculture. This trend is supported by the development of new, more sophisticated methodologies for assessing agricultural carbon, conducting MRV, and linking carbon sequestration to landscape planning and to larger conservation and rural development initiatives. At the same time, as the voluntary carbon markets mature, buyers are demanding more credible verification and assurance of the legitimacy and permanence of carbon credits. Two case studies in Box 4 illustrate some of these trends.

Box 4: Two Contrasting Examples of African Agricultural Carbon Projects

The Sofala Community Carbon Project in Mozambique and the Western Kenya Smallholder Agricultural Carbon Finance Project are two agricultural carbon projects engaging smallholder farmers in a variety of sustainable land management activities. The former was among the first such projects, while the latter is just now beginning.

Sofala Community Carbon Project, Mozambique

The Sofala project works with smallholders in Mozambique to promote sustainable land management by generating and selling verifiable emission reductions (VERs). Participating smallholders can choose from a suite of agroforestry, avoided deforestation, and forest conservation practices. For each agroforestry or forestry mitigation activity that a producer decides to adopt, a contract is established with the project developer, Envirotrade. To date, over 1,700 producers have signed nearly 4,500 agroforestry contracts. In addition, the forestry system was adopted on nearly 9,800 ha. These activities are projected to sequester 2,132,715 tCO_2-eq over the project's calculation period of 99 years. From 2002-2009, the project produced 476,210 tCO_2-eq, of which 168,740 tCO_2-eq has already been sold.

The remaining 307,470 tCO_2-eq, which are now held by the project developer, and all new VERs generated after the baseline was established in January 2007, are subject to the Climate, Community, and Biodiversity Alliance validation by auditor/certifier Rainforest Alliance. Environtrade markets the carbon offsets generated by the projects, negotiates the sale of the carbon offsets, raises additional finance where necessary, pays taxes on carbon offset sales, carries out research, and administers and develops new projects.

The carbon credits themselves are issued through Plan Vivo. One advantage of Plan Vivo for farmers is that they receive up-front payment for implementation of practices in the first seven years, based on the anticipated stream of carbon sequestration for the entire 99 year calculation period. This sequencing of payments helps farmers overcome the up-front investment hurdle of transitioning to new management practices. The assumption is that the new practices, once implemented, will be more profitable for farmers and thus economically sustainable for the indefinite future without the need for continued payments. However, this and other characteristics raise concerns about the legitimacy and permanence of the credits, and have the potential to negatively affect the marketability of the credits and the price that they can command.

Western Kenya Smallholder Agricultural Carbon Finance Project

The Western Kenya project also aims to sequester carbon through the adoption of sustainable agricultural land management (SALM) practices, during the period from 2009-2029. Farmers can select from six specific land management practices (e.g. tillage, manure additions, agroforestry) in three cropping systems (coffee, maize, and Napier grass) based on results of successful demonstration projects. By adopting these practices, participants can increase yields, earn additional income from participation in the carbon market, and enhance their resilience to climate change. The project developer, Swedish Cooperative Center-Vi Agroforestry (SCC-ViA), is promoting adoption on approximately 45,000 ha. In 2009, over 16,500 households were sensitized and over 8,100 committed to adopting practices. In 2009, SALM practices were implemented on about 7,000 ha, sequestering about 10,500 tCO_2-eq in the first year. By, 2029 the project is expected to have sequestered 1,236,373 tCO_2-eq equivalent, or an average of about 60,000 tCO_2-eq per year and about 1.4 tCO_2-eq per ha per year. To increase the assurance for buyers that the credits will remain legitimate and permanent, 60% of the sequestered volume will be held in reserve by the project developer to act as a contingency buffer.

The World Bank BioCarbon Fund (BioCF) is both the project investor and the carbon buyer, while SCC-ViA extension staff provide advice and training on sustainable agricultural production and marketing. The BioCF will sign Emission Reductions Purchase Agreements with ViA to purchase carbon credits resulting from the project, and, in turn, seek to sell these credits to various secondary buyers. The World Bank also facilitates meetings between SCC-ViA, BioCF investors, and carbon buyers and disseminates project information globally in international forums. One of the challenges of the project, and other similar ones, is the high cost of MRV (see the next sub-section on financial viability). The project submitted a SALM methodology and is currently undergoing validation from the Voluntary Carbon Standard.

The review of agricultural projects in Africa also assessed the role of different actors in these projects. A key role is that of the project developer or investor—the entity that initiates the project and provides the initial capital to get it started. As shown in Table 6, a wide range of organizations can play this role.

Table 6. Project developer/investor types in African carbon projects involving farmers (*n* = 59). Source: Shames and Scherr, forthcoming.

Institutional types	% of projects developed by this type of actor alone	% of projects in which this type of actor played a development role
Private carbon developer	20	28
Multi-lateral/bi-lateral donor	19	41
Private business, not primarily carbon	10	15
International environmental NGO	8	24
International development NGO	8	10
Private foundation	0	3
Research institution	0	8
Local/national government	0	2
Local/national company	0	2

The review by Shames and Scherr (forthcoming) and a feasibility study of an African agricultural carbon facility by Forest Trends and other collaborating organizations (2010) identified several additional key challenges and trends in the development of African carbon markets that reach smallholders. Specifically:

- Such projects can help build institutional capacity for sustainable land management; however, significant capacity is also a pre-requisite for successful project development, as smallholder carbon projects almost always require collaboration among farmers and groups of farmers at multiple scales.
- Similarly, the feasibility of aggregating and marketing carbon credits can be greatly improved if carbon can be integrated into existing value chains (e.g., for coffee) and supported by existing extension systems. Developing this infrastructure anew is likely to make carbon projects prohibitively expensive.
- Distributing carbon finance payments to individual farmers is often a challenge. However, a variety of innovative approaches have been attempted or proposed to distribute benefits equitably while minimizing transaction costs. One approach is to use carbon finance revenues for community-scale projects, such as health care, education, or infrastructure. An alternative approach is to distribute payments to individuals, but through lower-cost means such as credits that are issued and redeemed electronically through cell phone infrastructure or other means.
- As in most payment for ecosystem services projects, one important question is the way in which payments are allocated. Typically, in smallholder carbon projects in Africa, farmers are compensated on the basis of practices implemented (e.g., number of trees planted or land management changes adopted), not on the ex-post measurement of the actual amount of carbon sequestered on the farm. This approach tends to reduce transaction costs; however, to be legitimate, the practices must be closely linked to actual carbon sequestration outcomes, and these outcomes must be measurable through reliable proxies.

Financial Viability of Smallholder Agricultural Carbon Projects in Africa

Even as numerous pilot projects are underway to demonstrate the potential of carbon finance to support smallholder farmers and other low-income land stewards, questions remain about the financial viability of such approaches. In reality, the financial viability of many projects to date is difficult to assess because such projects have tended to be subsidized through donor, government, or NGO support for initial financing, technical assistance, MRV, research, and other functions. In some cases (e.g., the World Bank BioCarbon Fund), secondary buyers for carbon credits are sought, but not always found.

Several studies have assessed the economic potential of CA and related practices for carbon finance. A recent report by Forest Trends and others (2010) evaluated the economic viability of two agricultural carbon projects in Kenya: the Western Kenya Smallholder Agriculture Carbon Project (profiled above) and the Kenya Smallholder Coffee Carbon Project. The study evaluated each project’s transaction and implementation costs in relation to projected carbon revenues under different price scenarios. Estimated project implementation costs (including costs for extension workers, project managers, and MRV) were estimated at $2.39 per hectare per year, based on a project covering 200,000 ha. However, these estimates may be low because they exclude costs such as vehicles and office costs. The estimates also assume that MRV will be relatively inexpensive (only $0.50 per hectare per year) because crop yields will be used as a proxy for soil carbon sequestration. Based on these relatively ambitious assumptions, the authors estimated a minimum efficient agricultural carbon project size of about 62,500 ha, equivalent to about 100,000 tCO_2-eq/yr, and generating about $500,000 per year at a lower-end price of $5/$tCO_2$-eq and $3 million per year at a higher-end price of $30/$tCO_2$-eq. However, it is important to note individual sustainable land management initiatives that reduce GHG emissions and sequester carbon would not need to be this large; it is only the management of the carbon components of the project that would need to be aggregated at this scale.

The authors of the Forest Trends report summarize the prospects for agricultural carbon finance in Africa as follows: “Overall, under present conditions, our assessment suggests that carbon finance alone will be inadequate to defray the risks and costs of interventions affecting agricultural carbon stocks at a regional or landscape-scale. The low carbon yields over long periods and the lack of widely-approved methodologies for appropriate activities, implies that the risks will be high and returns low initially.” These conclusions about the prospects for agricultural carbon finance are echoed by Graff-Zivin and Lipper (2008), who found that returns from the sale of carbon credits associated with soil carbon sequestration on their own are unlikely to increase CA adoption, due to low prices of emission reduction credits and low annual rates of soil carbon sequestration. Some reasons for the low carbon revenues accruing to farmers include high transaction costs, long value chains, low carbon prices, modest sequestration rates per farmer, and the disadvantaged negotiating position of farmers relative to other supply chain actors.

Perhaps the most notable conclusion from both empirical and modeling work on smallholder agricultural carbon projects is that the principal benefit of such projects to small farmers is not likely to be the carbon payments themselves, but rather the implementation of new agricultural practices that provide higher and more stable yields, as well as increased institutional support and social capital for community-based adaptation and innovation. In this context, one option is to pool revenues from agricultural carbon projects to support other adaption-building strategies, such as crop insurance schemes and local agricultural credit facilities. Many initiatives (including COMESA/TerrAfrica, the Convention to Combat Desertification, and the BioCarbon Fund Phase 3) have thus begun to characterize agricultural carbon finance as “sustainable land management + carbon”—in other words, adding a carbon finance component to existing rural development programs that are effective and well-targeted in their own right. In such cases, proponents are clear that carbon finance should not become the “tail that wags the dog.”

This relatively pessimistic assessment of the economic viability of smallholder agriculture carbon projects may need to be modified, however, if such projects are re-cast as integrated landscape initiatives in which agricultural plots are managed in concert with other lands that are not under cultivation in any given year. The carbon stocks represented by such non-cultivated lands—and their potential for enhancement—is often much greater than the stocks within farm plots themselves. As illustrated in Figure 5, for example, the sequestration potential associated with avoided deforestation and degradation (burning) is more than twice that of all of the evaluated plot-scale practices combined. Soil and residue management (i.e., CA as it is sometimes more narrowly construed) constitute an even smaller sliver of the total mitigation potential of agricultural landscapes. To move from agricultural carbon to agricultural landscape management as the biophysical basis for carbon finance projects requires a broader landscape perspective that formally links sustainable agriculture at the household and village scale to improved natural resource management (specifically, ecosystem restoration and reduced degradation) outside of cropped areas. Some mechanisms for doing so are presented below, in the discussion on Question 3.

Question 5: Synergies and Tradeoffs among Multiple Objectives

This section addresses the question: “What are the key synergies and tradeoffs among climate change adaptation, climate change mitigation, food security, poverty alleviation, and ecosystem protection?” Information on the various outcomes of CA and the interactions among these outcomes is provided above, in the literature review. Given the diversity of CA practices and the range of different outcomes, there are a multitude of possible synergies and tradeoffs between and among the various food security, ecosystem conservation, climate change adaptation, and climate change mitigation objectives. However, in our literature review and interviews, some tradeoffs and synergies emerged repeatedly in relation to CA in sub-Saharan Africa. These turn out to be some of the key considerations for designing effective CA projects, and are discussed further below.

Livestock Management and Competition for Biomass

In many African ecosystems, biomass is a critical limiting resource. Limited water availability and natural soil fertility constrain primary productivity in native ecosystems, and the extraction of biomass as a result of crop harvests, firewood collection, or other uses can easily create a situation where annual biomass removal exceeds replenishment. Management of biomass—particularly crop residues and mulches—is a critical component of CA and a major constraint to its adoption in many places. Competing uses of biomass include fodder, cooking fuel, and materials for fencing, roofing, and handicrafts. In some places, termites consume much of the biomass that humans or livestock do not. Additionally, residue is perceived as harboring pests and diseases. Farm families burn crop residues for this reason, or to facilitate land clearing or the hunting of small mammals.

Livestock is an important part of most smallholder farming systems, but the management of grazing livestock may severely hinder CA adoption in Africa. Crop residues are often an important source of livestock feed during the dry season, and farmers may not feel that they can afford to leave residues in the field while their animals go hungry. Where communal land tenure is in place (as it is in many smallholder regions of Africa), fields often become available for communal grazing following the harvest. In this instance, farmers cannot choose unilaterally to exclude livestock for the sake of implementing CA. This decision must be made at the community level, and it is often difficult to change long-standing laws and customs. Regardless of the tenure system, community-level spatial management of land and natural resources can help improve compatibility between CA and other resource uses, including livestock production. Education and support for such community processes can therefore help support CA.

Derpsch (2008) suggested that one possible solution to the perceived tradeoffs between livestock raising and the adoption of CA is to plant unpalatable cover crops that livestock will not consume. However, many farmers have little interest in investing in crops that have no human or livestock consumption value, but do have tangible costs in terms of seeds and labor (L. Gatere, Cornell University, pers. comm.). Another solution is to plant fodder trees and shrubs within fields or as part of CA rotations. Integration of fodder trees to farming systems in Tanzania and Malawi has been successful, and has improved dairy cattle health. As a result, farming households have improved family nutrition and are able to generate additional income from selling milk (Chakeredza et al., 2007). Similarly, ICRAF's Evergreen Agriculture program is promoting CA that includes nitrogen-fixing trees and shrubs that will eventually become permanent features on farms, supplying plant nutrients, mulch, and fodder every year while remaining out of reach of the grazing mouths of free-range livestock (ICRAF, 2009).

Yield vs. Adaptation: Tradeoff or Straw Man?

There is both theoretical and empirical support for the notion that maximal crop yields are inconsistent with high levels of system resilience (Darnhofer et al., 2010). The highest-yielding cropping systems of the United States and Europe are perilously dependent on fossil fuel-derived inputs, banking and financial systems, global markets, crop subsidies, and other supports, and in many places are continually depleting the natural capital of topsoils and groundwater aquifers. Conversely, biologically diverse traditional agroforests and extractive reserves of the tropics are likely to be quite resilient, but are generally not very productive or profitable (Palm et al., 2005).

Between these two extremes, however, there is much evidence that both yields and adaptive capacity can be increased simultaneously. Intercropping, crop rotations, and crop diversification can foster complementarity of resource use (of soil nutrients, water, labor, etc.), thus boosting aggregate productivity while decreasing the chance that all will be lost in any given growing season. On poor soils, agroforestry or tree-based farming systems that produce crops in a park-like setting under the canopy of high-value trees may actually be more profitable and more resilient than systems focused on solely on annual crops (Verchot et al., 2007). Maintaining diverse crop species and varieties in rural communities may entail a small yield penalty—not all varieties will do as well as the top-yielding variety in a given year—but may provide valuable protection against crop pests, diseases, or climate change in the future. This protection may ensure that household income never dips below a critical poverty threshold, although income in the good years may be lower than in a less diversified system.

The message emerging from these examples is not necessarily to avoid the adoption of technologies such as high-yielding seeds or inorganic fertilizers, but to adopt only those technologies that are context-appropriate and to do so in conjunction with resource conserving strategies that build natural capital, which can then be relied upon in the event that the technologies become ineffective or unaffordable.

Ecosystem Service Markets and Carbon Finance: Co-Benefits or Co-Harms?

As discussed above, carbon sequestration and GHG emissions reductions in agroecosystems are often fully complementary with a shift toward more productive, resilient, and conservation-friendly agricultural systems. However, the sale of carbon credits in most cases constitutes a legal agreement to implement—or refrain from conducting—certain practices or activities, often for an extended period of time. For example, farmers may agree to plant a certain number of trees and avoid cutting those trees for a period of years or decades; or they may commit to particular agronomic, livestock management, or cropping practices. Even if these practices are generally supportive of rural livelihoods, the contractual nature of the carbon finance arrangement in and of itself limits farmers' future options. Rural communities in many parts of the world have developed finely-tuned systems for identifying environmental signals and responding by changing agricultural practices, expanding or culling livestock herds, migrating, and so forth. It is important that carbon finance projects do not undermine such traditional and indigenous adaptation strategies.

Thus, where possible, carbon finance arrangements and contracts should be designed with contingency arrangements or options for farmers in the event that the prescribed practices become untenable due to future environmental change. Insurance schemes or carbon offsets held in reserve can be used to ensure that the credits themselves are permanent and legitimate, without locking farmers or communities into arrangements that may undermine their future livelihoods.

CARE has developed a pro-poor approach to carbon finance that already embodies some of these concepts, and others that are intended to ensure that any payment for ecosystem services (PES) project contributes livelihood co-benefits (CARE, 2009b). This approach includes the following principles:

- Poverty reduction benefits of carbon finance should reach poorer households, women, and other marginalized groups within poor communities.
- Carbon finance schemes should have no negative social impacts, or, where such impacts are unavoidable, provide effective mitigation measures that achieve a net "do no harm" outcome.
- Benefits should be equitably shared between local, national and international levels.
- Human rights must be respected, protected and secured.

Timing of Synergies and Tradeoffs

When examining synergies and tradeoffs, the time frame of analysis is all-important: many practices that would generate synergies in the long term result in short-term tradeoffs. This is true for a wide range of farm and household decisions, including CA. Without an ability or willingness to invest up-front capital or labor to overcome short-term tradeoffs, farmers are never able to achieve long-term synergies, and remain mired in poverty traps. As discussed above, CA is very often an example of this phenomenon. To implement CA, farmers must initially invest in new machinery, seeds, and possibly herbicides, and may experience increased initial labor demand. In some cases, benefits may be realized in the first year, but in other cases, it may take years for synergies to be achieved.

PES (including carbon finance) has been proposed as one way of helping farmers to overcome investment hurdles to achieve long-term synergies associated with highly-functioning, carbon-rich agroecosystems. However, it is not always the best strategy to overcome particular sets of short-term tradeoffs. If major capital investments are required for equipment, infrastructure, seeds, seedings, and so forth, loans (or donor-funded contributions of these inputs) are often more effective than the smaller capital streams that PES is likely to generate. If knowledge and human capital are the limiting factors to adoption of new practices, then these constraints should be specifically targeted through training, extension, farmer field schools, or similar methods. These points are all fully intuitive, but, surprisingly, have often been overlooked in recent dialogues about the potential of PES as a mechanism for supporting poverty alleviation.

Results: Options for Future Program and Policy Action

This chapter addresses Question 3 (opportunities to increase climate change adaptation and mitigation benefits through CA) and Question 6 (policy options and priorities for supporting CA). These questions address the three levels at which CARE and WWF may influence the design, effectiveness, and scale of CA activities in sub-Saharan Africa: 1) through individual projects; 2) through country- or continent-wide programs or portfolios of activities; and 3) through policy advocacy to influence other actors within national governments, international organizations or conventions, or donor agencies.

Question 3: Opportunities to Increase Climate Adaptation and Mitigation Value

This section addresses the question: "How could CARE and WWF modify existing CA approaches and practices to enhance their value for climate change adaptation and mitigation?" Generalized principles and recommendations for "climate friendly" agriculture are already available, but offer limited guidance for project development within specific contexts. This section provides more specific options and recommendations for the design of CARE and WWF projects and programs involving CA for climate change adaptation and mitigation. The section begins by reviewing opportunities and challenges of the existing projects visited in Tanzania and Mozambique. It then integrates this empirical evidence and lessons learned with other considerations (e.g., funding constraints and opportunities, political and institutional contexts, carbon market characteristics, etc.) to identify promising opportunities for project design for to enhance adaptation and mitigation benefits. The final sub-section presents options for the design of CA programs or portfolios to achieve such benefits over a larger scale.

Analysis of Existing Projects

The four projects visited for this study reveal many of the key challenges and opportunities for increasing climate change adaptation and mitigation benefits through CA, in conjunction with long-term livelihood security and ecosystem conservation. These highlights, challenges, and opportunities are analyzed below.

HICAP Project (Tanzania): Highlights, Challenges, and Opportunities

The CARE-led Hillside Conservation Agriculture Project (HICAP) seeks to support 4,400 households in Tanzania's Uluguru Mountain region to implement CA and associated community development activities to increase food security while protecting surrounding forests and watersheds. The project has made substantial progress toward these goals, but local communities remain challenged by resource governance issues and weak law enforcement.

Project highlights:

- Dramatically higher crop yields (+100-300%) and farmer profits (up to +500%)
- Village savings and loan (VSL) groups support investment in household and small business development (e.g., water pumps, bicycles, metal roofs, livestock)
- Construction of the Center for Sustainable Living, a regional training and demonstration facility
- Extension model that combines CARE employees with seconded government extension workers
- Multi-pronged technology diffusion model through CARE demonstration plots, contact farmers, and ongoing experimentation by farmer field schools (FFS)
- Increased cooperation between genders due to collaborative structure of VSL and FFS groups

- Promotion of ripping with “double-digging” for soil preparation increases soil moisture and reduces weeding labor; the required farm implements are locally manufactured

Key challenges:

- Many farmers rent their land, which may inhibit long-term investment
- Burning of the forest understory and other uncultivated areas is rampant, contributing to loss of carbon stocks and possibly an impairment hydrological functions (e.g., water courses have dried up, but this link has not been verified by formal study)
- Insufficient social and political capital to enforce laws and address external impacts, particularly burning
- Annual precipitation is reportedly declining, and the onset of the rainy season is becoming more erratic
- Communities are distant from markets, limiting access to inputs and buyers
- Without a strong institutional partner, it is unclear who will provide continued backstopping after the project ends

Future opportunities for enhancing project benefits:

- Incorporate small livestock for improved diet and manure production
- Plant fruit trees on steep slopes
- Implement small-scale water harvesting and irrigation
- Further develop the incipient relationship with the local seed company Tanseed to assist farmers as both producers and consumers of quality seed
- Improve market linkages by fostering relationships with nearby input suppliers and buyers
- Support communities to advocate for their interests at the village and district levels, including for law enforcement to reduce burning and resource extraction from outside pastoralists
- Link CA to reduced degradation of non-cultivated areas (including forest) to generate greater carbon sequestration benefits

EPWS Project (Tanzania): Highlights, Challenges, and Opportunities

The CARE-led Equitable Payment for Watershed Services (EPWS) project promotes CA, agroforestry, and farm terracing to help increase food security, reduce erosion, and encourage re-forestation in a critical sub-catchment in the Uluguru Mountains that contributes to Dar Es Salaam’s public water supply. Although population density in the valley is relatively low, shifting cultivation of very steep slopes in recent years had led to severe erosion, sedimentation, and land degradation. Market linkages were weak, and communities had few opportunities to earn cash income. The project is promoting the use of CA, farm terracing, agroforestry, and reforestation of very steep slopes to reduce erosion and focus agriculture in the more suitable and less sensitive lower reaches of the sub-catchment. Composting, small livestock raising, and other practices are being used to increase soil fertility and eliminate burning as the standard means of field preparation.

Project highlights:

- Dramatically increased yields following adoption of recommended practices
- Increased water flows in the local tributary as measured by a gauging station
- Local tree nursery is producing seedlings for fertilizer trees and timber trees
- Demonstration of a pilot-scale payment for watershed services (PWS) model in which water users in the Dar Es Salaam area compensate local land stewards for practices that reduce erosion and sedimentation
- Introduction and initial adoption of terracing to reduce erosion
- Small livestock enclosures and composting to create organic fertilizers

- Education of para-professionals to provide training, outreach, and backstopping after the project formally ends

Key challenges:

- Terrace construction exposes mineral soil and may reduce soil fertility in the short term
- Continued ability to monetize ecosystem service values, following the conclusion of the pilot PWS project, is uncertain
- Annual precipitation is reportedly declining, and the onset of the rainy season is becoming more erratic
- Market linkages are weak, due in part to poor road access

Future opportunities for enhancing project benefits:

- Incorporate additional CA practices into farming systems, e.g., continuous soil cover and intercropping
- Scale up successful agronomic practices to further intensify agriculture on permanent plots in the lower reaches of the watershed
- Promote agroforestry and forest regeneration in the upper half to two-thirds of the catchment to generate substantial long-term benefits for watershed protection and carbon sequestration that are easier to measure and market than piecemeal benefits under a shifting cultivation system

Quirimbas National Park CA Project (Mozambique): Highlights, Challenges, and Opportunities

This WWF project supports sustainable agriculture within Quirimbas National Park to help improve the viability of sedentary agriculture and thereby minimize pressure to destroy or extract resources from sensitive habitat areas while also reducing human-wildlife conflict. Overall, 130,000 people live within the National Park, mostly in villages that were present at the time the park was established, several years ago. The spatial integration of wildlife habitat, villages, and farm plots has created problems with human-wildlife conflict that have proven to be quite intractable.

Project highlights:

- Increased production in previously food-insecure communities means that many families now have enough to eat throughout the year
- Successful promotion of mulching and crop residue retention instead of burning fields
- Successful promotion of contouring, trenches, and dikes to retain moisture and lessen erosion
- Construction of improved post-harvest storage facilities using local materials
- Initial success toward efforts to consolidate agriculture into community blocks, as opposed to dispersed fields that are more vulnerable to wildlife damage
- The project cooperates closely with a local NGO called Kulima, which functions as a strong field partner
- Implementation of a tiered extension model that includes a strong presence of local extension agents, demonstration farmers, and contact farmers

Key challenges:

- Protecting crops from wildlife (especially elephants) remains a stubborn problem despite considerable investment in cultural and technological practices to minimize conflict
- Within the past decade, warmer climate has increased the disease burden, while increasingly erratic rainfall patterns have led to more frequent crop failures
- Availability of quality seeds is a major constraint, and there is no private sector seed business in the area

- The initial project was too short to implement the full CA package and supporting practices
- Indiscriminate burning of woodlands exacerbates human-wildlife conflict and reduces habitat value and carbon stocks of uncultivated areas within the National Park

Future opportunities for enhancing project benefits:

- Foster local seed multiplication businesses or other sources of certified seeds
- Rejuvenation of the local cashew industry for cash income
- Compost animal manure for fertilizer
- Increase coordination among the several donor-funded projects and the agricultural demonstration and training center within the National Park
- Take advantage of proximity and access to Pemba and Ibo Island to increase market linkages for agricultural crops, based on an integrated value chain analysis and strategy
- Link CA and sustainable livelihoods to REDD to improve the effectiveness of existing REDD initiatives in the park and support local communities through these initiatives
- Re-design the National Park to reduce human-wildlife conflict, improve biodiversity conservation, and facilitate law enforcement by creating a new spatial plan that designates separate areas for total protection, resource conservation and use, and agricultural and community development

Inhambane CA Project (Mozambique): Highlights, Challenges, and Opportunities

This CARE project seeks to raise crop yields and household incomes in a drought-prone area by helping farmers improve soil fertility, seed systems, and water management systems. An ambitious extension model has reached more than 15,000 households. However, given the very low levels of pre-existing capacity and social capital in the project area, additional technical support will be important to solidify and build on gains made toward sustainable, community-driven agricultural development.

Project highlights:

- Average yield increases of 40-50% for maize and sorghum in the target population
- The hunger period has been reduced from an average of 5-6 months per year to two months per year
- Tiered extension models involving professional extensionists, community “demonstrators,” and farmers groups
- Strong engagement of women in agricultural innovation and farmers groups
- Year-round irrigated vegetable production with CA in communities close to the Vilanculos urban market
- Farmers groups have implemented key support functions such as group seed banking and construction of improved post-harvest storage facilities
- More than half of farmers in target area adopted at least four recommended soil fertility and moisture management practices

Key challenges:

- In an area that already had marginal rainfall for agriculture, the rainy season is becoming shorter and more erratic
- For the most part, farmers groups are still in the early stages of solidifying their capacity and self-sufficiency, and it is unclear whether they be able to persevere after the project ends
- Many households in the project area are still not food secure
- Since mulching tends to be more work than burning, there is the possibility that farmers will revert to extensive slash-and-burn practices
- Traditional beliefs and habits inhibit the uptake of CA and other recommended practices

- Reliable sources of quality seed may not be available once the project ends
- Although there are government extension workers in the district, they are essentially absent from the rural areas where the project operates

Future opportunities for enhancing project benefits:

- Rejuvenation of the local cashew industry for cash income
- Potential for cooperative direct marketing of cash crops
- Foster increased availability of inputs (especially seeds) through farmer training and establishing relationships with private seed sellers

Improving Climate Adaptation in CA Projects

This sub-section provides a set of "best-bet" options for increasing the benefits of CA projects in helping rural households and communities adapt to climate change. This sub-section pertains mainly to farm- to village-scale management practices, while the next sub-section on linking agricultural development and conservation objectives focuses more on landscape-scale opportunities.

Learning from Success

Many or all the CA projects visited—and others in CARE's and WWF's African portfolio—are already implementing effective approaches. These approaches can be replicated and expanded upon in future CA projects. Some of the main success stories include:

- Broadly across the projects studied, CA appeared to be increasing household- and community-level resilience to climate change by increasing crop yields, improving moisture retention, enhancing soil fertility, and bolstering the knowledge and capacity of farmers to respond to novel circumstances or threats.
- In contrast to conventional agricultural development projects in nearby areas, the CA projects have placed a strong emphasis on soil fertility and water management. Benefits of these practices are reflected in higher yields, even in the first year of adoption.
- CA is being taught and promoted as a farming approach, not as a cookbook recipe. This learning model is appropriate given the nature of CA as an agroecological strategy for managing the complex dynamics of multiple ecosystem components. To implement this learning model, projects have paid considerable attention to local capacity building, participatory learning, establishing new village-level organizations (such as farmer field schools), and building social capital for intra- and inter-household cooperation and knowledge-sharing.
- Rather than treating CA as a stand-alone set of agronomic practices, the projects have recognized the importance of complementary agronomic issues and constraints such as seed availability and post-harvest storage.
- CA has proven to be an effective means of engaging women in agricultural innovation, livelihood improvement, and financial education and management. All of the studied projects placed a strong emphasis on the formation and capacity building of various types of farmers groups, and these groups generally included strong female representation. In some cases, the groups consisted predominantly or entirely of women, while in other cases, mixed groups helped foster collaboration between the genders. Empowerment of women in these ways has also been demonstrated to yield catalytic benefits for household and child wellbeing.

CA Practices and Associated Activities to Increase Climate Adaptation Benefits

One frustration of CA project managers, revealed through many of the interviews, is the perennial feeling that as soon as one constraint is solved, it becomes apparent that many other constraints are inhibiting progress toward sustainable livelihoods and climate change adaptation. However, this situation is also an indication of project success since it suggests that the most severe constraints are being addressed, allowing communities to move onto other challenges, which are sometimes larger external or structural constraints that are more challenging to address. Learning from the complementary successes of many past CA projects, it may be possible to design future projects that address more key constraints early in the project cycle. However, since it takes time to build trust, increase capacity, and implement new agricultural practices, the reality is that CA practices almost always need to be implemented in phases over several years. The "expanding orbits" model shown in Figure 2 illustrates this idea.

Based on the collective experience of past CA projects in sub-Saharan Africa, following is a set of "best bet" practices and activities that could be incorporated into CA projects to increase climate change adaptation potential. Although these practices are broadly applicable, their relative priority or sequencing will vary by context and can be evaluated through participatory assessment during the project planning phase.

- **Rainwater harvesting** in arid or semi-arid environments, using locally appropriate technologies. Depending on the slope and soil type, these could include basins or Zaï pits, contours or bunds, or larger scale structures where project resources allow.
- **Small livestock raising** (e.g., chickens, pigs, or goats) to increase protein supply and provide high quality fertilizer for CA. Livestock enclosures may facilitate collection and composting of manure for soil amendments.
- **Planting of fruit trees**, including species that are drought resistant and ripen at different times of the year, as an emergency food source.
- **Incorporation of fertilizer trees and shrubs** within and at the margins of fields to provide an endogenous source of nitrogen fertilizer. Fast-growing annual legumes and nitrogen-fixing shrubs can increase soil fertility in the first year of adoption, while planting of nitrogen-fixing trees such as *Faidherbia albida* can be an effective long-term strategy, particularly in places where free-ranging livestock are likely to eat any palatable plants within reach.
- **Improvement of post-harvest storage facilities** to safeguard harvests from pest damage and increase buffering against seasonal hunger.
- **Improvement of seed systems**, including local seed saving through community institutions and social networks (to ensure self-sufficiency) in conjunction with public or private organizations that can supply new seed species and varieties (to benefit from new technology and increase resilience drought, disease, and pests).
- **Financial capacity-building**, including education on principles and negotiation techniques for purchasing inputs and selling products, as well as support for community-based savings, investment, and credit infrastructure, such as VSLs or other similar models.

These "best bet" practices are all supplements to a core CA strategy, which must be tailored to the local environment for any given project. Although many context factors are relevant, perhaps the three most important factors to consider in designing the CA strategy are the local population density, amount and variability of rainfall, and soil type. Below are two examples of how the core CA strategy might be tailored for different contexts: a high population density, low rainfall environment, and an environment with lower population density or higher biomass availability.

In an area with high population density and relatively low rainfall, biomass availability is typically a major constraint, and there is likely to be little surplus arable land available. In this context, the cropping system itself must provide multiple resources, including food, soil nutrients, cooking fuel, and livestock feed. Without the opportunity to maintain long fallows, crop rotations and intercropping with nitrogen-fixing species will be critical for maintaining soil fertility. Agroforestry will likely be an appropriate strategy, and can incorporate a mix of fertilizer trees, fruit trees, and trees that can be coppiced for firewood or fodder. Depending on the tree species, these may be interspersed in fields or, more commonly, managed as live fences, homegardens, or small woodlots. Intensification will occur by means of greater labor intensity to manage available biomass (e.g., crop residues, animal and green manures) for optimal soil fertility benefit. To protect valuable biomass in the fields (e.g., tree seedlings and crop residues), animals may need to be penned. In a very biomass-constrained environment, application of mineral fertilizers may be necessary for sustaining soil fertility, or at least for "kick-starting" productivity on heavily degraded sties. Even with these investments, high population density and low rainfall will limit opportunities for climate change adaptation.

In an area with lower population density and/or higher quantities of aboveground biomass, farmers will have more management options, but the selection of practices will depend on returns to key inputs, particularly labor. In such contexts, fallows and shifting cultivation may have been historically used to maintain soil fertility. Where these practices are less labor-intensive than cultivation of permanent plots, they are likely to be favored. Nevertheless, promotion of intercropping, nitrogen-fixing shrubs and herbs, mulching, water harvesting, and other CA practices on cultivated plots may alter the relative desirability of shifting cultivation and permanent cultivation. This may result in the abandonment, or at least diminution, of shifting cultivation practices. If permanent cultivation is adopted, the fertility of these plots can continue to be subsidized by regular influxes of biomass from nearby uncultivated areas in the form of mulch. With ample biomass for cooking fuel, fodder, and mulch available from nearby uncultivated lands, agroforestry might not be perceived as a worthwhile investment. However, planting of fruit and timber trees is still desirable to increase farmer income and insurance again drought and hunger.

Project Design Considerations

In addition to the specific practices discussed above, the overall design of CA projects with respect to factors such as funding, duration, and project logical frameworks (logframes) may be critical to their success in promoting benefits for climate change adaptation. Following are recommendations for orienting CA projects to support climate change adaptation:

- **Project duration:** Because of the novelty and complexity of CA for farmers that are accustomed to traditional farming methods, adoption is often a gradual process. Many farmers adopt CA practices in the second or third year of a project, while late adopters take longer. "Expanding orbits" of supporting activities also tend to be introduced gradually, while newly formed farmers groups take time to build the trust, capacity, and confidence necessary to work together effectively with minimal external support. For all these reasons, the typical three- or four-year duration of a rural development project is often too short for a CA project. In the worst case, projects of this length come to a close just as momentum is starting to build but before it is sustainable, causing most gains to disappear after a few years. Longer projects (at least five years in duration, and preferably seven) are more likely to be successful in bringing about a critical mass of adoption and local capacity to sustain and expand project gains after the project ends. Such capacity is especially important for addressing novel threats, such as climate change. Longer projects also allow local institutions to 'graduate' from a focus on immediate constraints to work on more complex challenges such as management of cash crops using market information to maximize profit from the sale of these crops. Donors are often reluctant to fund projects of five years or more. However, in the case of CA, most of the benefits of a longer project could be realized by reserving a relatively small portion of the total project budget (e.g., 15-20%) for years 5-7 to provide a reduced level of technical backstopping for groups that were established during the main portion of the project.

- **Project flexibility:** Inherent in the concept of adaptation is maintaining the flexibility to respond to changing conditions. Such flexibility can be constrained by project logframes that specify *a priori* not only the project objectives and targets, but also the means by which these targets will be achieved. In many ways, this type of project planning is valuable for ensuring that projects are well-designed and accountable. However, if adaptation is considered to be a major project goal, then projects should have flexibility to work with community groups to help address challenges as they arise. One way to build such flexibility into projects without losing too much rigor or accountability is through logframes that focus less on specific activities than on outcomes, including the development of local capacity.

- **Include capacity building targets and indicators:** Related to the previous point, a project's success in fostering resilience to climate change in the long term depends to a significant degree on the capacities and knowledge base of local farmers, farmers groups, and communities. Targets and indicators for such outcomes can and should be specified and monitored throughout the project cycle.

- **Incorporate adaptation planning explicitly:** A climate change adaptation "lens" can be helpful for designing projects and prioritizing activities to foster adaptation. CARE has developed and begun to use a set of participatory tools for doing so (see Appendix 3). Such tools can be used in participatory appraisal, project design, monitoring, and staff training.

- **Orient management strategies to household constraints:** In most contexts, there are many possible ways of adopting CA. For instance, soils may be covered with mulches or cover crops, and weeds may be removed manually or with herbicides. Each adoption pathway will place different demands on various input factors (e.g., land, labor, and capital), and each will provide different sets of benefits (e.g., reduced overall labor, reduced labor for women, higher yields, etc.). Since input constraints and livelihood needs and priorities tend to differ by household, CA projects, too, should design mechanisms for customizing CA adoption approaches to household circumstances.

- **Include a spatial dimension:** To the extent that CA introduces new tradeoffs—such as livestock management on post-harvest fields—such tradeoffs can often be addressed by taking a larger spatial or temporal perspective. For instance, designation of grazing areas that are available for communal use in the dry season may allow large livestock grazing and CA to co-exist. Spatial management of multiple natural resources can help support such solutions, but may require new capacities and institutional structures for resource assessment, negotiation, and management.

- **Allow for larger scale perspectives:** To varying degrees, external factors and constraints may inhibit adaptation efforts, even when great progress has been made at the community level. For this reason, it is valuable to consider exogenous political and economic factors as part of project appraisal and planning exercises and, when appropriate, include a component in the project budget to address such issues. This component could include, for example, an initiative to clarify the land tenure system to increase incentives for long-term investments in soil fertility, or support for district level land-use planning and zoning activities. Such efforts could also include advocacy training to help communities petition for support or resources from district or higher levels of government.

- **Address barriers to adoption at multiple levels:** Adoption of CA may require wholesale shifts in farming practices, which may be deeply embedded in the fabric of rural communities. In this context, efforts to promote CA through diffusion from an initial set of receptive farmer groups or demonstration farmers may not be successful if the remainder of the community is strongly resistant to these new ideas. Multi-tiered educational and outreach strategies that work broadly with entire communities may help address this challenge.
- **Develop a backstopping "mosaic" for post-project sustainability:** Most of the CA project sites visited for this study received little technical support from local government entities or NGOs. This situation raises concerns about the long-term sustainability of agricultural development efforts, particularly in the context of climate change. The potential opportunities for long-term technical backstopping vary considerably by site, but there are usually at least some local organizations that could fill this role. A "mosaic" of backstopping resources should be assembled beginning early in the project cycle so that community groups are familiar with the resources available and establish relationships with the appropriate individuals or organizations. This approach recognizes that different actors (e.g., local and district government; private input vendors, buyers, and traders; local and international NGOs) may be available and useful in different ways, but that no single source should be counted on to be available for the indefinite future. Community groups should receive training on how to identify and access the resources they need.

Implementing some of these project design options will require the cooperation of donors. Through regular contact of CARE and WWF staff with donor organizations, these points can be articulated and, perhaps through repetition, gradually incorporated into funding priorities and frameworks.

Improving Climate Change Mitigation and Conservation Linkages in CA Projects

The CA projects evaluated in this study did not collect data on carbon sequestration or the provision of other ecosystem services. However, based on field observations, interviews, and data from the literature review, it appears that the projects we evaluated generated relatively few benefits for climate change mitigation or ecosystem conservation. This general result likely holds true for many, if not most, other CA initiatives in sub-Saharan Africa. Key factors limiting the provision of conservation benefit include:

- Rates of soil carbon sequestration associated with CA are generally very low, if net sequestration occurs at all. Net carbon gains in aboveground biomass are also very low, except where trees have been planted. However, none of the study projects have resulted in extensive tree planting.
- Opportunities to link CA and the provision of sustainable permanent-plot agriculture to the conservation of native ecosystems (and their carbon stocks) in nearby areas exist in principle, but have not been achieved in practice. This outcome is not surprising in places where investments in CA are not formally or conditionally linked to the desired conservation outcomes (e.g., reduction of forest encroachment or burning). Absent such strong linkages, entrenched cultural practices dictate the continuation of annual burning and other practices that degrade or destroy native habitats.

As with other aspects of CA project design, the most promising pathways for increasing carbon sequestration (and associated co-benefits for biodiversity conservation and watershed protection) depends on the project context. In areas with relatively low population density and considerable standing forest or woodland resources, by far the most promising opportunity for CA to generate significant climate change mitigation benefits is by supporting the reduction of deforestation and forest degradation (REDD)—or the regeneration of former forests—in nearby areas. For instance, in Quirimbas National Park, two existing REDD initiatives are faltering because local residents continue to establish charcoal kilns in forests designated for protection. Alternative livelihood strategies such as CA could theoretically reduce such pressures; however, to achieve these benefits will require strengthening the formal and conditional linkages between CA and ecosystem conservation. Doing so goes well beyond the purview of typical CA projects into the realms of natural resource governance, land tenure, and law enforcement, as well as integrated assessments of livelihood strategies (see Box 5).

In areas with high population densities and relatively little standing forest or woodland, carbon can still be sequestered within agricultural plots, fallows, and agroforests. However, net mitigation benefits are likely to be much lower (see the earlier analysis of carbon sequestration potential of CA). For this reason, it generally makes little sense to design a CA project in this context to maximize carbon sequestration. Instead, projects should be designed for sustainable agricultural yields, the provision of ecosystem services to agriculture and local communities, and improved local livelihoods and resilience to climate change. Co-benefits for carbon sequestration are likely to follow from projects that pursue this set of priorities.

Finally, in all contexts, it is worth noting that many climate change adaptation strategies have historically been very bad for native ecosystems. Charcoal production, logging, and hunting are all, at times, potential strategies for coping with the loss of food production and farm income. These options continue to remain important for many communities in Africa, and in many cases it may not be ethical to forestall such opportunities. For the purposes of project design, however, the goal should be to promote climate change adaptation strategies that do not degrade the local environment.

Box 5. When is an Integrated Landscape Approach Worth the Bother?

As discussed above, there are many compelling reasons to integrate local CA investments with broader landscape management. However, there are also real costs to doing so—costs related to coordination and communication activities, political capital, and increased risks associated with the greater complexity and uncertainty that is often present at larger scales. It is therefore helpful to establish criteria to assess when it might be a worthwhile to adopt an integrated landscape approach to agricultural development through CA. Doing so may be especially important when:

- The effectiveness of CA at the local level is strongly influenced by exogenous political or economic factors.
- Significant benefits could be gained—or risks addressed—by coordinating farm and village scale agricultural activities with conservation and natural resource management in a larger area. For instance, at the HICAP project site, seasonal grazing by pastoralists from outside the project area is creating resource use conflicts in the woodlands surrounding villages where CA is being promoted. Upstream-downstream dynamics in watersheds may also indicate a need to work at landscape scale.
- Larger-scale planning, zoning, or management designations strongly dictate the permissibility or appropriateness of land-use activities at the project site. For instance, in Quirimbas National Park, where CA is being promoted in many communities, park land-use restrictions technically prohibit agricultural development in many places where it is taking place, although such restrictions are not enforced. On the other hand, the park’s zoning plan—and park management’s failure to enforce it—is probably exacerbating human-wildlife in ways that significantly increase livelihood vulnerability.

When engagement at the landscape scale is indicated, it can be achieved in different ways. Where strong community involvement is necessary for developing integrated multi-scale solutions, it may be appropriate to incorporate landscape management fully into the project's participatory processes, taking deliberate steps to link actors at the community, village, district, or other scales. For instance, at the HICAP project site, issues such as law enforcement (e.g.. to control impacts from burning and cattle grazing) and access to extension services may be most effectively addressed by participation of community groups in the political process. In other situations, it may be sufficient for landscape-level considerations to be incorporated into the design and management of a CA project by the implementing organization. In this case, landscape coordination is achieved by aggregating investments and practices in multiple communities, but it may not be necessary for local communities themselves to engage in these broader-scale issues.

The planning and design of a CA project should consider whether a landscape approach may be worthwhile. At a minimum, assessments should be conducted to identify any major landscape level factors, constraints, or policy conflicts (e.g., conflicting land-use designations) that may inhibit the attainment of project goals.

Program and Portfolio Design

Based on the evidence presented in this report, there are strong arguments in favor of mainstreaming CA as a rural development and poverty alleviation strategy in the work of organizations such as CARE and WWF. This sub-section presents a few considerations for the design of an overall CA program or portfolio for sub-Saharan Africa. A first consideration is the availability of funding mechanisms for supporting CA at a larger scale. Fortunately, there are several new and emerging funding sources related to climate change adaptation and mitigation, which, although not necessarily typical agricultural development funding sources, may be well-suited to funding CA (see Box 6).

Box 6. Funding Opportunities for CA

Although funding for agricultural development in Africa overall remains, by most assessments, quite limited, CA has the potential to emerge as a "growth industry" in agricultural development financed by domestic sources and foreign donors. One reason is that CA projects may be able to tap sources of funding beyond the traditional agricultural development sources, particularly when it promises substantial benefits for climate change adaptation and mitigation. Examples of such opportunities in sub-Saharan Africa include:

- Significant new donor and national government funding sources for agricultural development are in the pipeline, including financing through the World Bank and the U.S. Feed the Future initiative. The investment priorities and programs put forward by national governments in a number of countries already explicitly include CA. There is much scope to expand the role for CA within these investment programs, particularly in relation to climate change adaptation goals.
- Within the African climate policy community there is considerable interest in CA, broadly defined, as a climate change mitigation strategy that could have strong sustainable development and adaptation co-benefits. Some pilot projects are being implemented in the voluntary carbon offset market, and more are in the pipeline. Now that REDD+ has been endorsed, opportunities for incorporating CA components to ensure farmer benefits are of interest. As guidelines for Nationally Appropriate Mitigation Actions (NAMAs) are

developed, there will almost certainly be provision for CA in some countries.

- Funding sources for risk reduction and disaster assistance may be interested in CA as an operational strategy. For instance, the U.S. Office of Foreign Disaster Assistance (within USAID) in Mozambique is exploring CA as a possible disaster risk reduction approach, particularly for addressing drought risks.
- Mainstream agricultural funding programs and paradigms may be modified in incremental ways to support CA. For instance, mechanization programs to increase tractor availability and use can support CA if such tractors are fitted with direct seeding equipment instead of with conventional plows. Similarly, programs focused on seed- and fertilizer-driven agricultural development can support CA by bringing such inputs to places where farmers are experimenting with CA, or by promoting CA in conjunction with these improved inputs.
- Bi-lateral funding sources that invest heavily in environmental conservation may be interested in financing CA due to its possible benefits for conserving ecosystem services and sequestering carbon. In this context, CA may be positioned as a more versatile and durable "alternative livelihood strategy" for biodiversity conservation projects that seek to reduce human pressure on threatened natural resources by supporting less destructive economic development options. In contrast to "silver bullet" alternative livelihood strategies that have often been associated with biodiversity projects, investment in CA can help build knowledge and capacity that allow communities to implement a suite of agroecologically-based livelihood strategies that can respond dynamically to changing economic and environmental conditions.
- Under the title of Sustainable Land Management, NEPAD's TerrAfrica program and its donors (principally GEF) and national partners are funding more than two dozen projects to reverse the process of land degradation, focused on smallholder farmers. CA is an appropriate strategy in many of these contexts, and is being promoted explicitly in some of the projects.

The priorities of these funding sources suggests that CA projects will often be more appealing to a variety of donors if they go beyond a narrow approach to CA (e.g., site-scale tillage, soil cover, and crop rotation practices) to strengthen linkages between CA, ecosystem conservation, carbon sequestration, and rational planning and management of landscape mosaics to increase synergies among production, conservation, and livelihood goals.

A second consideration is targeting and site selection for CA projects. As demonstrated in this study, CA can support poverty alleviation and climate change adaptation in a wide variety of contexts. However, the need to prioritize the use of limited resources (both for NGOs such as CARE and WWF and for the donors that fund them) dictates that efforts be focused where they can do the most good. Assessments of CA relative to likely alternative scenarios for specific regions can be helpful in making such allocation decisions. Such assessments may reveal, for instance, that a CA project would yield fewer net benefits in a region with ample rainfall, flat terrain, and relatively fertile soils than in an semi-arid region where effective soil and biomass management could make the difference between hunger and plenty.

On the other hand, if an agricultural area is unlikely to support sustainable livelihoods even after implementation of CA and supporting activities, then CA may represent a poor investment. This notion of not investing in "sinking ships" may seem at odds with the humanitarian outlook of many development NGOs and donors. However, in the modern world of changing climate, it is important to be realistic about what types of strategies are likely to lead to adequate and resilient livelihoods and what types of strategies may lead to development dead ends. Rainfed agriculture is an inherently risky livelihood strategy in dry areas, and, over time, may become completely untenable in some places where it was once marginally possible. In areas where CA may not be a strategic investment because of long-term drying trends or other environmental changes, communities should be assisted in other ways to develop new livelihood strategies that are more appropriate for the evolving environment. In some cases, this may involve emigration to other areas.

A final consideration is the potential role of the CARE-WWF Alliance in future CA programs or portfolios for sub-Saharan Africa. This point also touches on issues of targeting, as well as mapping out complementary roles for CARE and WWF that advance both organizations' priorities while take advantage of each organization's comparative advantages (see Box 7).

Box 7. Opportunities for the CARE-WWF Alliance to Advance Effective CA

The CARE-WWF Alliance represents an exciting opportunity for two well-respected organizations to work more effectively to manage rural landscapes for multiple conservation and poverty alleviation benefits. By working together, the two organizations can draw on their respective strengths to tackle complex challenges in a more comprehensive way, without excessive "mission drift" that can have a tendency to pull organizations away from their core objectives and competencies. Much thought has already gone into the purpose and functioning of the CARE-WWF Alliance as an institution. This box explores opportunities and issues for the Alliance to work specifically in the context of CA projects. Three points are addressed: roles for linking conservation and development, targeting of project activities, and opportunities to systematize project learning to support effective policy advocacy.

Linking Conservation and Development

As discussed earlier, many CA projects have made significant progress with respect to agricultural yields and poverty alleviation, but not with respect to potential environmental benefits including carbon sequestration. In many cases, realizing these co-benefits will require stronger linkages between conservation and development objectives and activities. The Alliance can play an important role in strengthening these linkages by building on the strengths of each organization.

For instance, WWF has comparative advantage in the technical aspects of wildlife and biodiversity, watershed management, landscape planning, and advocacy for sound environmental protection, regulation, and governance at the ministerial level. Meanwhile, CARE has strong abilities in community-based agricultural development and local capacity-building, and in health, education, and support for women.

These complementary strengths can be tapped to link conservation and agricultural development activities. For instance, WWF has begun to develop REDD projects in several countries. In the context of REDD, CA, perhaps implemented or guided by CARE field offices, could help reduce pressure on forests by supporting alternative livelihoods that do not rely on deforestation. For WWF, such an approach would require adapting the REDD concept to mixed land-use mosaics that have a significant proportion of non-f land. As another example, WWF could lend valuable expertise in contexts such as the HICAP and EPWS projects, where landscape- or watershed-scale natural resource management issues impinge on the livelihood of local people, and where planning, coordination, and perhaps advocacy at these larger scales will be necessary to achieve significant environmental co-benefits.

Targeting

When CARE and WWF collaborate on field-based projects through their Alliance, the understood goal is to advance the missions of both organizations. These missions overlap to some degree, but not entirely, and criteria for targeting priorities may be even more divergent. In the case of CA, potential projects should be evaluated relative to each organization's strategic priorities, individually. Opportunities that are well-aligned with both sets of priorities may be good candidates for the Alliance to implement joint field projects. Opportunities that are high-priority for one organization but a lower priority for the other may be candidates for other project models, in which WWF supports or advises CARE with respect to specific project components, or vice versa, without equal commitment to project implementation on the part of both organizations.

From Projects to Policy

Finally, the Alliance can play an important knowledge-sharing and strategy setting role for CARE and WWF. Lessons learned from CA and other sustainable agriculture projects across Africa—many of which are synthesized in this report—can support design of more effective projects and be used to identify the most important policy and structural constraints that might be addressed through joint advocacy efforts.

Question 6: Policy Options and Priorities for Supporting Climate-Friendly CA

This section identifies opportunities for improving policies at the sub-national, national, and international levels to support climate-friendly CA at a much larger scale across sub-Saharan Africa. Policy and structural barriers to the mainstreaming of CA in Africa have been characterized generally (e.g., Thiombiano and Meshack, 2009), and include:

- Levels of investment in agricultural development from both domestic sources and foreign aid remain very low. For instance, the share of agriculture in Official Development Assistance declined from 19% in 1980 to 3% in 2008 ($4 billion of the total $158 billion committed) (FAO, 2010b). Investment in sustainable land management represents an even smaller sliver of total investment in rural development and poverty alleviation.
- There is relatively little awareness of CA on the part of decision-makers in both the public and private sectors. Absent a major natural catastrophe, issues of soil fertility generally fail to capture the interest of policy makers. High-level political commitments may therefore be needed to support CA at a broader level, but these commitments have rarely been forthcoming.
- Government extension services supporting smallholder farmers are essentially absent or highly inadequate in many countries. Extension support from NGOs fills this gap only to a limited degree, and only in some places.
- Similarly, CA has not been significantly incorporated into the university curricula and adult education programs that train agricultural development professionals. Research on CA is taking place in some African countries, but rarely at the scale needed to develop the most appropriate context-specific management options.
- To the extent that national agricultural policies affect small- and medium-sized farms at all, these policies often support conventional agriculture and are at odds with encouraging CA.
- Where CA is officially supported, this support tends to be poorly integrated with other investments in poverty reduction, infrastructure, and rural development within national budgets and strategies.

- Land tenure systems are often not conducive to CA, particularly where individual farmers have only use rights, not ownership rights, to land. This arrangement can inhibit long-term investment in soil fertility and ecosystem management.

Scaling Up CA in Africa: A Perspective from South America

As indicated by this list, there remain many significant barriers to mainstreaming CA in sub-Saharan Africa which, in aggregate, appear quite daunting. To understand how the African continent might move toward sustainable agriculture at a large scale, it is helpful to consider the experience of South America in recent decades. While socio-economic, cultural, and environmental conditions differ widely, some lessons may be transferable.

In parts of South America CA has now become a mainstream—or even default—approach to agriculture. In Brazil, more than 60% of the nation's cultivated land (more than 25 million ha) is managed as CA (Mello and van Raij, 2006). Experimentation with no-till in Brazil began in the early 1970s, and in many cases adoption was the only viable option for farmers, who found themselves in a "change or perish" situation due to devastating soil erosion and economic pressure (Bwalya and Friedrich, 2002). CA was initially practiced among large-scale farmers, who learned from the U.S. experience and from local experimentation (Kassam, 2009). As farmers began to see the economic and environmental benefits of CA, experiences and practices began to be shared more widely among farmer groups, then supported by local governments, and later promoted by the national government.

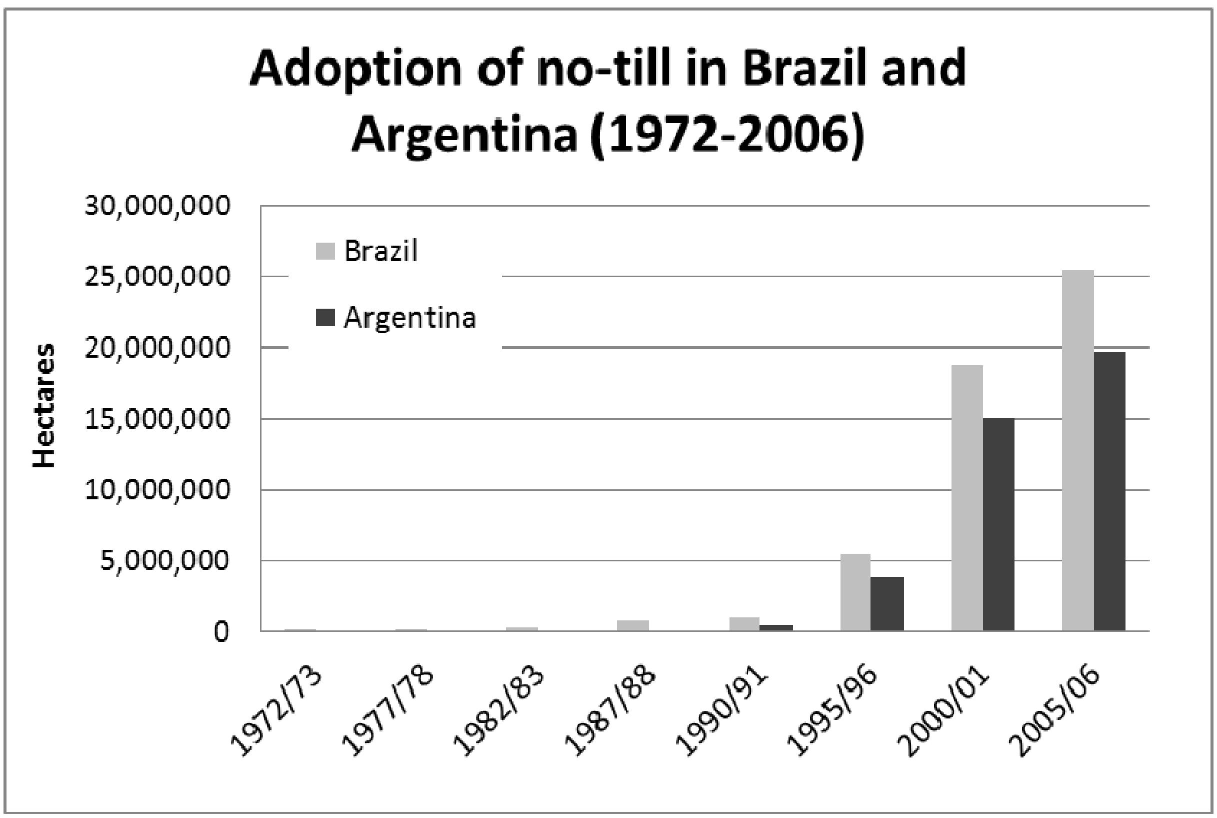

Figure 6. Adoption trajectory for no-till farming (a principal component of CA as it is commonly practiced in South America) in Brazil and Argentina, 1972-2006. Data sources: FEBRAPDP for Brazil and FAO (2008) for Argentina.

Multi-stakeholder involvement and strong institutional and policy support are some of the keys to the paradigm shift seen in Brazil (e.g., through the Brazilian Agricultural Research Corporation, the Brazilian Federation of No-Till Farmers, and EMBRAPA), Argentina (e.g., through the Argentinean Association of No-Till Farmers), and Paraguay (supported by the Ministry of Agriculture with GTZ funding). Mainstreaming of CA in South America has also been supported by research and development by universities, state and federal research and extension groups, and agricultural input and equipment manufacturers (Derpsch et al., 2010). While CA has now become the norm in parts of South America, adoption did not accelerate rapidly in Argentina or Brazil until about one million hectares was under CA cultivation, a process that took 15-20 years (see Figure 6). As in Africa today, major constraints during these first two decades included lack of institutional support, technical knowledge, and availability of inputs and equipment. Only once farmers had demonstrated, through a critical mass of adoption, that CA could be sustainable and profitable at the field level did government and other organizations provide the institutional and policy support needed to fuel the exponential growth in CA that has resulted in its dominant place in South American agriculture today.

Another critical message from the South American experience is that engaging large-scale farmers in CA is likely to important for demonstrating its commercial value and scalability, and therefore building interest in this approach from political leaders and from agriculture and finance ministries. Without significant adoption by large commercial farmers in Africa, CA will remain of interest primarily as a food security and poverty reduction strategy—a policy realm that has a specific, but limited, set of advocates and funding sources. On the other hand, if CA adoption accelerates rapidly among commercial farmers, it may also come to be perceived as a strategy for economic development, increased generation of export products and foreign exchange, and basin-scale environmental management. These policy realms tend to have complementary—and potentially larger and more powerful—sets of advocates and funding sources. With a broader coalition of advocates, it is more likely that supportive national policies and technical assistance for CA will develop. Even if such supports are oriented mainly to assist to the commercial agriculture sector, many benefits are likely to accrue to smallholders practicing CA, ranging from better knowledge of CA among agriculture and rural development professionals to improved availability of CA machinery.

In 2008, a workshop on scaling up CA in Africa sponsored by the FAO, Japanese government, and several African agricultural organizations proposed a goal of transitioning at least 30% of Africa's farm and rangelands to CA management by 2015. This target is probably not achievable within the next few years because a critical mass of adoption has not been reached in very many African countries. However, if grassroots promotion and adoption efforts demonstrate CA to be a profitable and sustainable approach, including for commercial agriculture, experience from South America suggests that greater institutional support could follow within a decade or so.

Policy and Investment Options to Mainstream CA in Africa

With some notable exceptions, CA in Africa has tended to be promoted by specific donor-funded projects or pilot initiatives, not as part of broader programs. As a result, adoption and benefits have been limited in scale, and sometimes have been fleeting if the project was not successful at building sufficient capacity and institutional support to sustain CA activities. Based on many interviews and the field work conducted for this study, the single most effective way to scale up CA for smallholder farmers is to vastly increase extension support and technical backstopping. Since the successful adoption of CA requires a departure from conventional farming methods—supported by a new knowledge base—there is really no substitute for a dense network of trainers and extensionists at the field level. This is particularly true for the many parts of Africa where existing levels of capacity are very low due to low educational attainment, geographic isolation, or past internal displacement or war.

Considerable evidence from recent CA projects suggests that, where training and extension services function well, relatively little additional external support may be necessary. This is because CA is predicated on the use and management of local natural resources much less than on the application of external inputs, and can be conducted effectively either with or without mechanization. While NGOs are certainly providing excellent extension and technical backstopping services in many areas, it is unclear whether this model of support is fully scalable. Yet, there remain many impediments to the implementation of effective, full-scale government agricultural extension services. These constraints include lack of funding, the lack of a service-oriented extension culture in many places, and insufficient knowledge and capacity on the part of existing and prospective extension workers. However, all of these barriers may be addressed through investment and policy change. Effective extension programs for CA will likely have the following characteristics:

- Focus on smallholders in addition to commercial growers. As some governments perceive the smallholder sector as contributing little to national economic output, a smallholder focus may require some external investment as part of poverty reduction efforts.
- Distributed models for knowledge sharing and dissemination—using both modern and traditional technologies and media—to reach farmers in isolated areas.

Other agricultural policies could also be shaped to support CA more strongly. At present, some agricultural policies are actually counter-productive for CA. For instance, subsidies or programs to “modernize” agriculture by introducing tractors and plows may discourage no-till agriculture and direct seeding. Import taxes on farm machinery may disfavor CA if equipment for conventional agriculture is manufactured domestically but the more specialized CA machinery needs to be imported. Subsidies for specific crops may discourage the use of crop rotations and intercropping that supports soil fertility. And fertilizer subsidies may discourage the judicious use of external inputs through synergistic approaches such as CA, instead promoting indiscriminate fertilizer use that can pollute water supplies and inhibit the development of soil-based ecosystem services. Modification of such perverse policies can help place CA on a level playing field with conventional agriculture.

While Green Revolution agricultural development programs have sometimes been characterized as antagonistic to CA (and, in practice, often are), new investments in African agricultural development offer possibilities to create synergies between CA and Green Revolution technologies. In reality, effective CA requires the use of good seeds and appropriate inputs, while such inputs can be put to more efficient use in the context of resource-conserving soil and water management as well as community- to landscape-scale management of natural resources. These ideas have been incorporated into the plans and stated interests of major African development initiatives such as the Alliance for a Green Revolution in Africa and Feed the Future. It remains to be seen how fully and how effectively these strategies are pursued.

It is important not to ignore the tension that exists in some countries between agricultural development paradigms that favor national food security (at an aggregate level) and export-led growth from the agriculture sector, and paradigms that are more focused on local food security and livelihood support for small farmers. While these approaches need not be mutually exclusive, the reality of limited resources means that, in practice, there tend to be tradeoffs between investments in these approaches. According to the Country Director for CARE Tanzania, for instance, that country’s “Farmers First” agriculture strategy is a Green Revolution approach focused on larger and better capitalized farms. Staff at CARE Mozambique reported a similar emphasis of national agricultural policies in that country. Nevertheless, CA is an adaptable and scalable strategy, and may have an important role to play in African commercial agriculture.

Advocating for a re-orientation of national agricultural development priorities is likely to be challenging, especially given that there are often good reasons to invest in commercial agriculture (e.g., job creation and generation of foreign exchange). A complementary approach is to position sustainable land management investments such as CA as helping to advance the goals of multiple sectors and ministries. From an investment standpoint, CA may be attractive as a strategy for watershed protection, flood damage mitigation, reduction of agrochemical pollution, reduction of deforestation, climate change adaptation, and HIV/AIDS care. The purview for these concerns spans multiple ministries including environment, disaster reduction and risk mitigation, health, and forestry. It may therefore be fruitful for advocacy efforts to target these ministries.

Strategic Roles for CARE and WWF

There are already quite a few national and international efforts to promote CA in Africa by various NGOs as well as national programs in a small but growing number of countries (e.g., Malawi and Zambia). The FAO sponsors a global network of CA practitioners and advocates. Internationally, there remain very different communities of practice related to CA, reflecting a range of perspectives on the use of agrochemicals, different scale and commercial orientation of farmers, and the incorporation of CA in broader sets of practices including agroforestry and organic agriculture. In this context, CARE and WWF, as international NGOs, can contribute in some important ways to advocating for an improved policy and structural environment to support the scaling-up of effective CA to support poverty alleviation, ecosystem conservation, and climate change adaptation and mitigation. Based on interviews with numerous personnel from both organizations, we identified the following activities as among the most promising ways in which CARE, WWF, and their Alliance could support CA at the policy level:

- Advocate for CA as a worthwhile rural development and conservation strategy within the bi-lateral donor agencies of the countries where CARE and WWF have international offices (e.g., the United States, United Kingdom, and Denmark).
- Cultivate CA champions within key regional institutions such as NEPAD and the Southern African Development Community. This may be supported by the work of the Rural Futures Initiative and other multi-sectoral policy activities.
- Within WWF, conduct “in-reach” to staff and country offices to explain the potential benefits of CA as a strategy for watershed management, REDD, buffer zone management, alternative livelihoods, and integrated landscape planning. Provide access to resource materials and experts to help incorporate CA into these types of projects where appropriate.
- In CARE’s agricultural development work, assess and, if appropriate, work with community members and leaders to address, dimensions of local land tenure systems that inhibit the viability and effectiveness of CA.
- For CARE, WWF, and its Alliance in both international and country offices, help raise awareness of CA and its benefits in dealings with external parties—for example, at professional and program meetings, donor meetings, and interactions with in-country government staff at all levels.

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Appendix 1: Examples of CARE and WWF CA Initiatives

Table A1-1. Examples of CARE and WWF conservation agriculture initiatives in sub-Saharan Africa. Source: documents and interviews with CARE and WWF personnel.

Location / Organization	Context and Challenges	Project Goal	Key Activities: Planting (P), Tillage (T), Fertilizers (F), Irrigation (I), Extension (E)
Angola (CARE)	Low rainfall on lavras; potential for small scale irrigation of more moist nacas that are near streams; population pressure; fields getting farther from homes because extensification used as coping strategy	Sustainably improve agricultural productivity and livelihoods in communities with many ex-combatants by introducing integrated CA techniques and Village Savings and Loans	Zero tillage (T); promotion of animal manure, compost, and crop residues to reduce utilization of chemical fertilizer (F); constant soil cover to reduce water loss (I); farmer field schools, building capacity of government ministry (E)
Ghana (CARE)	Erratic rainfall; long dry season; decreasing total rainfall (around 800-850 mm/yr); frequent drought; deforestation for wood fuel; annual bushfires	Improve livelihood security of small farmers through a participatory technology development approach that promotes long-term sustainable management and conservation of soils and natural resources to improve crop yield and production	Contour ditches and barriers with perennial crops (P); minimum tillage (T); compost pits and heaps, rotational kraaling (F); stakeholder-led training curricula, community-based extension agents, farmer field schools, field days, learning visits (E)
Liberia (CARE)	Rainfall 1,700-2,080 mm/yr, 80-95% in rainy season; upland and lowland cultivation; decreasing fallow periods due to population pressure and desire of farmers to cultivate lands closer to residences during the war; low fertility driving extension of cultivated areas onto distant plots; deforestation	Revitalize agriculture: improve food security and income, in environmentally sustainable ways	Direct planting into slashed crop residues, row planting, terraces (P); no tillage in upland soils and reduced tillage in lowlands and in heavy soils (T); permanent soil cover with crops, trees, crop residue mulch, and leguminous cover crops, no burning (F); extension officers target farmer field schools and extend outreach (E)
Mali (CARE)	Rain-fed agriculture with 500-700 mm rainfall annually; insufficient wells for pastoralists; increased drought has driven extensification; decreased fallow periods; overgrazing and loss of ground cover; firewood extraction rates increased >200% in 15 years; hunting, extensive pastoralism, and wild fires degrade forest resources	10,000 agro-pastoralist households will sustainably improve their nutrition and food security status through introduction of CA techniques and gender-sensitive support systems	No-tillage, erosion control with stone barriers and hedges, wind breaks, gully treatment, integrated management of vegetable nutrients, fruit trees, post-harvest conservation techniques (T); targeted fertilizer inputs with biological approaches (F); small-scale irrigation schemes (I); community based trainers train farmer groups clustered into "learning labs" (E)

Location / Organization	Context and Challenges	Project Goal	Key Activities: Planting (P), Tillage (T), Fertilizers (F), Irrigation (I), Extension (E)
Mozambique-Nampula (CARE and WWF)	Erratic rainfall; periods of drought	Improve livelihood security of smallholder farmers in Nampula province; improve crop yield and production through introduction of sustainable soil fertility and water management systems	Permanent planting holes and thick mulching with crop residues (P); no inter-row tillage (T); neem and cashew firebreaks, contour ditches and barriers (T); composted manure, micro-dosing of fertilizers, cover crop and crop residue mulch processed by termites (F); training curriculum and volunteer demonstration (E)
Mozambique-Inhambane (CARE)	Low rainfall (400-800 mm); deforestation increasing rapidly; fields farther from homes; shorter fallow time	Raise crop yields and incomes for 18,000 smallholder farmers in drought-prone areas by introducing improved and sustainable soil fertility and water management systems and increasing adoption of drought-tolerant crop varieties	Permanent planting holes, contour ditches and barriers, thick mulching with crop residues (P); tillage restricted to planting holes (T); fertilizer micro- dosing, targeted use of fertilizer on high value crops (F); water retention in permanent planting holes (I); farmer groups provide training, demonstrations, and research into soil and water management-related subjects (E)
Mozambique-Quirimbas National Park (WWF)	Subsistence farming and fishing livelihoods within the recently-established Quirimbas National Park; poor soils, little indigenous agricultural knowledge, and human-wildlife conflict associated with livelihood activities within and adjacent to park boundaries	Raise crop yields and improve livelihoods in current agricultural areas; reduce the need to establish new agricultural plots; reduce human-wildlife conflict	Conservation tillage (T), planting on contours (P), water conservation program (I), crop diversification (P), farmer training on basic CA principles (E)
Sierra Leone (CARE)	Productivity low, due to various constraints: manual techniques, high pre- and post-harvest losses, lack of improved and diversified planting materials, poor water management, and sub-optimal technical skills; reduced fallow impacting fertility of upland fields	Introduce innovative agricultural practices that are more productive and more environmentally sustainable, benefiting 11,000 people, including marginalized groups	Land clearing without burning, leaving litter as mulch (P); no tillage in upland soils and reduced tillage on other soils (T); organic fertilization by using nitrogen fixing plants and compost (F); targeting existing farmer field schools, youth and women’s groups targeted for marketing training (E)
Tanzania (CARE)	>2,000 mm annual rainfall; erosion has led to sediment loading of local catchments; hilly terrain and high altitudes; declining	Improve viable and sustainable resource conservation to support the livelihood security of smallholders, through adoption of	Swales, contour bunds, direct planting, permaculture (P); deep texturizing of permanent production beds, minimal tillage

Location / Organization	**Context and Challenges**	**Project Goal**	**Key Activities: Planting (P), Tillage (T), Fertilizers (F), Irrigation (I), Extension (E)**
	fertility puts pressure to expand cultivation into forest reserve	sustainable CA practices and development of appropriate support systems and infrastructure	after beds created (T); introduction of chemical fertilizer over time (F); learning center for sustainable agriculture, farmer field schools, contact farmers, demonstration plots (E)

Appendix 2: Benefits, Barriers, and Challenges of CA

Table A2-1. Benefits, barriers, and challenges of CA from selected case studies in Africa.

Case study location (source)	Project summary	Benefits	Barriers and challenges
East Africa			
Kenya – Laikipia (Kaumbutho and Kienzle, 2007)	Two-year (2004-06) project to scale up and refocus CA, following RELMA conservation tillage pilots (1998-2002). Implemented farmer field schools, trained staff and farmers, brought in advanced equipment, advanced artisan training, and forged links with the private sector. Research on CA history and extent of adoption and adaptation to establish impact on food security for vulnerable households.	Improved soil quality, reduced labor requirements, reduced costs, increased cropping area	Access to inputs, credit, and markets in a relatively remote district with poor infrastructure; CA perceived as risky by smallholders; crop residue makes crops more vulnerable to insects and diseases; weeds become resistant to herbicides; smallholders lack access to equipment; prohibitive start-up costs; crop residue must be protected from thieves and grazing; decreasing labor supply due to emigration and HIV/AIDS
Kenya - Laikipia district (Liniger and Critchley, 2007)	CA system where soil is ripped using ox-drawn plows to improve water storage capacity and smallholder yields. 200 households adopted the technology without incentives. Kenyan Ministry for Social Services facilitated registration of CA self-help groups to improve household food security and income.	Higher yields, early planting and access to markets when prices are still high	Competing uses for crop residue; high equipment and animal maintenance costs; necessary to use herbicides
Kenya – Siaya (Kaumbutho and Kienzle, 2007)	Two-year (2004-06) project to scale up and refocus CA, following RELMA conservation tillage pilots (1998–2002). Implemented farmer field schools, trained staff and farmers, brought in advanced equipment, advanced artisan training, and forged links with the private sector. Research examined CA entry points, adoption, and adaptation.	Increased yields, saved labor, offered farmers an opportunity to see farming as a business, improved nutrition	Reluctance to use herbicides to control weeds; grazing livestock consume crop residue; traditional etiquette customs including that elders must plant before youth; missing links between farmers and service providers; land tenure system favors men

Case study location (source)	Project summary	Benefits	Barriers and challenges
Tanzania - Arumeru, Karatu, Mbeya districts (Shetto and Owenya, 2007)	Case studies in the three districts were carried out to document past and current CA practices and experiences, local adoption and adaptation, challenges, and future prospects.	Increase in yield, less labor to plant and prepare land, reduced soil erosion, improved soil fertility and structure, increased social interactions, improved livelihoods and ability to purchase implements, education for children, etc.	Weed control; competing uses for crop residue; grazing livestock consume crop residue; limited knowledge and availability of equipment; inadequate CA knowledge
Uganda - Pallisa, Mbarara, Mbale (Nyende et al., 2007)	Case study presents experiences and lessons learned from three districts, following CA pilots funded by FAO and Sida in 2000. The pilots introduced smallholders to CA through farmer field schools, with a focus on local implementation strategies.	Multiple benefits in terms of productivity (labor saved, income augmented, product diversity), sustainable use of natural resources (biodiversity and resilient land-use systems), environmental services (better water quality, reduced costs of erosion)	Adapting CA equipment such as knife-rollers and jab planters; assuring availability of CA tools and cover crop seeds after project closure; diffusion of successful technologies
Southern Africa			
Lesotho (Silisi, 2010)	Case study draws on the data collected by FAO in 2006 and examines *likoti*, the local CA adaptation of planting basins. Reviews impact of CA on sustainable crop production intensification.	Higher productivity, improved soil structure, enhanced fertility, improved livelihoods and social sustainability (including for the most vulnerable)	Support needed for buying initial inputs; initial labor intensiveness is a deterrent
Malawi (Mloza-Banda and Nanthambwe, 2010)	Study examines CA experiences in Malawi to document experiences from government and other interventions. It looks at the benefits and disadvantages of CA and the challenges of scaling up. Based on work commissioned by the Malawi National Conservation Agriculture Task Force with FAO support.	Reduction of labor, availability of labor for other livelihood activities, increased yields	Inappropriate soil fertility management; ineffective weed control under no-till systems; access to credit for seed, fertilizers and herbicides; lack of appropriate technical information for change agents and farmers; blanket introduction of CA that ignored resource status of rural households; competition for crop residues in free range communal grazing livestock systems
Zambia, Southern Province - Monze, Choma (Baudron et al., 2007)	Report describes a collaborative CA project between ACT, ASP, CIRAD, FAO and RELMA in Zambia, considered a CA success story. Examines CA technologies introduced to the Southern Province, and farmers' successes and challenges.	Improved yields (early planting, rainwater harvesting, etc.), spreading demand for labor allows for diversification, expansion of cultivated areas	Labor constraints (weeding time almost doubled under CA); difficulty of digging basins manually in dry soil; belief that crop residues harbor pests and diseases; communal grazing; fire; inadequate crop rotation; perception that CA is for food security and not for business

Case study location (source)	Project summary	Benefits	Barriers and challenges
Zambia - Central and Southern (Haggblade and Tembo, 2003)	The study examines financial incentives for farmers who switch to CA. Using survey data from the 2001/2002 cropping season, the study evaluates yield gains against input usage increases.	Improved soil structure and water retention, reduced for chemical fertilizers, increased crop yield	Increases weeding labor, at least in the early years following adoption; can take years to see benefits
Zimbabwe (Twonlow et al., 2008)	Case study describes CA efforts by a FAO-led broad-based task force. With a focus on vulnerable households, the task force developed a CA strategy called Precision CA that is being promoted by NGOs and national agricultural research and extension departments throughout Zimbabwe.	Spreads labor for land preparation over the dry seasons and encourages more timely planting, resulting in reduction of peak labor loads at planting, and higher productivity and incomes (increased average cereal yields by 50 to 200% in more than 40,000 farm households)	Low degree of mechanization; lack of appropriate implements; lack of appropriate soil fertility management options; problems of weed control under no-till systems; access to credit; lack of appropriate technical information for change agents and farmers; blanket recommendations that ignore resource status of rural households; competition for crop residues in mixed crop-livestock systems; labor availability
West Africa			
Burkina Faso and Niger (Reij et al., 2009)	Paper describes local CA adaptation in the Sahel, where agricultural practices were enhanced in simple, low-cost ways by farmers and promoted by local, national, and international actors. To improve water availability and soil fertility, farmers use planting pits and build stone contour bunds that capture rainwater runoff and soil.	Land rehabilitation (200,000-300,000 ha), increased food production (planting pits increased yields from virtually nothing to >400 kg), helps feed about 500,000 people, more tree cover, more crop diversity especially on rehabilitated land, people can cope better with drought , women can reallocate time they used to spend collecting fuelwood	Requires high initial labor inputs and, in the case of stone bunds, outside materials

Case study location (source)	Project summary	Benefits	Barriers and challenges
Ghana - Brong Ahafo, Ashanti (Boahen et al., 2007)	Study examines CA introduction and promotion, adaptation, and diffusion in 21 communities in Ghana. The study assesses successes and challenges, and identifies opportunities for further CA promotion.	Increased crop yields, labor use, weed control (through cover crops and herbicides), improved soil quality, farm incomes, reduced labor needs by 30%	Increased pests and diseases due to unburned mulch; maize fared poorly with specific cover crop; cover crops not perceived as beneficial if they lack economic value; fires; animal grazing; difficult to plant in mulch; scarcity and high cost of equipment; unavailability of cover crop seeds; limited funds for extension activities after projects ended; limited promotion
North Africa			
Morocco - Chaouia Ouardigha region (Liniger and Critchley, 2007)	No-till system with crop residue management for medium scale wheat and barley farming developed by Moroccan National Institute of Agricultural Research. Pilot farmers adopted technology with incentives, receiving all inputs for first 3 years.	Higher yields, lower costs; costs lower even when cost of drill is included	Drills expensive ($6,000, but 50% subsidized by government); cost of seeds and fertilizers, especially after subsidies are cut

Appendix 3: A Framework for Evaluating Climate Change Adaptation in CA

Much work has been done to define and understand the concepts of adaptability and resilience (see Box 3), and a few frameworks are especially helpful for evaluating climate change adaptation in farming systems in the context of this study. Researchers at the World Agroforestry Centre have recently coined the concept of "sustainagility" to refer to humans' ability to adapt to changing biophysical and socioeconomic environments in rural landscapes (Verchot et al. 2007). In their conception, sustainagility includes biophysical resources and management practices as well as human capital (knowledge and skills), social capital (institutions and cooperative relationships), financial capital, and physical capital (such as roads and irrigation infrastructure). It also spans multiple scales, reflecting the range of ways in which households, communities, and societies react to change: for instance, responding to a localized pest outbreak requires one set of capacities, while responding to a prolonged drought or prolonged depression in crop prices might necessitate broader shifts in livelihood strategies and management practices. These concepts can be illustrated by a "sustainagility ladder" (see Figure A3-1).

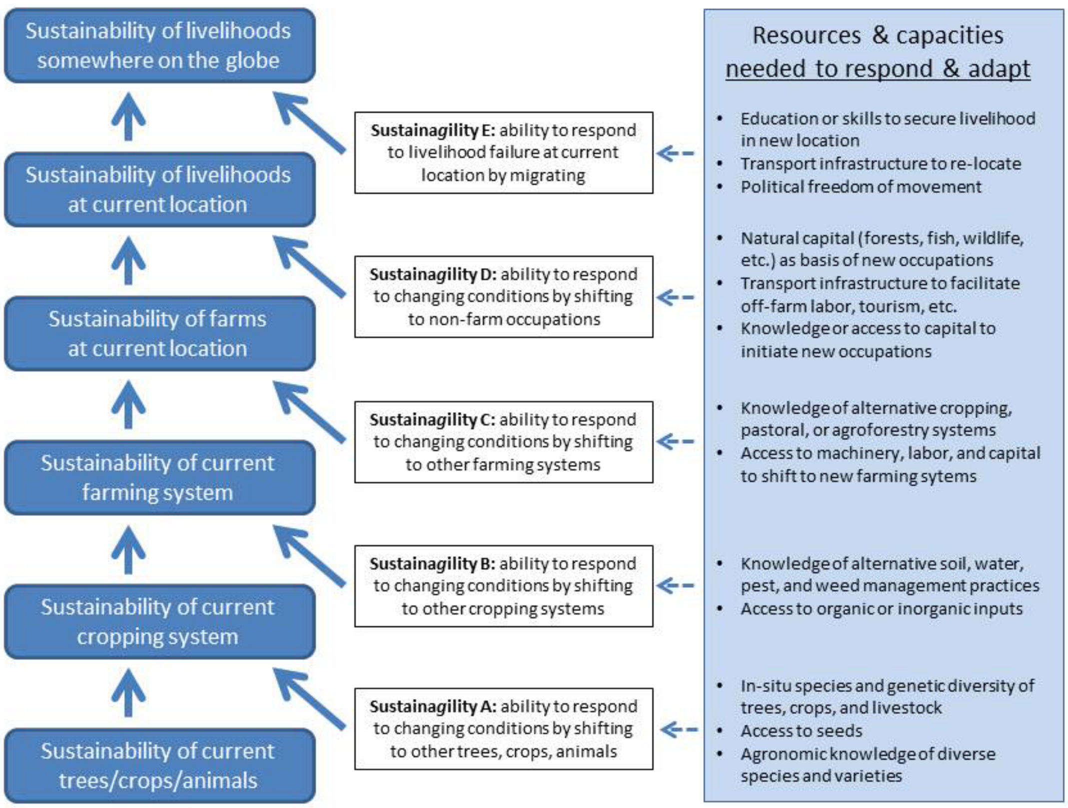

Figure A3-1. "Sustainagility ladder" illustrating a hierarchy of adaptation approaches at increasing scales and in response to increasingly severe environmental or economic disturbances. Beginning at the lower left, farmers can assemble sustainable cropping systems based on currently productive trees, crops, and animals plus the ability to substitute new species and varieties in response to shifting conditions. Ascending the ladder, additional types of adaptive capacities are needed to ensure sustainable livelihoods within broader realms of analysis. The right-most column indicates some of the resources and capabilities that rural households may need to manage food production systems and livelihood needs at each level. Figure is after Verchot et al. 2007.

Embedded within the concept of sustainagility is the capacity of famers and communities to conduct adaptive management and to recognize and respond to changing conditions in a decisive manner. This ability, in turn, requires that rural communities are already possess a knowledge base and set of tools that enable then efficiently to diagnose new challenges, evaluate potential courses of action, implement the most promising changes, and evaluate outcomes so that the system may be adapted further as needed.

Another relevant thread of research on adaptability and resilience has examined historical responses of farming systems and civilizations to external perturbations, including climate change. Part of the challenge in developing measures of resilience or adaptability for contemporary agricultural systems is that these properties can, in reality, be determined only after the system has actually experienced major changes (e.g., progressive warming or drying over the course of years or decades) or shocks (e.g., major droughts or severe price swings for agricultural inputs or products). Examining the response of past agricultural systems to actual perturbations of the types that are anticipated for the future is one way of making rational predictions about which system attributes are likely to enhance future adaptiveness. Some such attributes may appear to be obvious, while others may have more ambiguous or nuanced effects.

Based on his examination of collapses of several past food systems (including drought-triggered famines in Ethiopia from the 1960s through 1990s), Fraser (2007) proposed the heuristic of a three-dimensional space to assess the resilience or vulnerability of a system to climate change (see Figure A3-2). We call this the “adaptability cube.” Fraser’s work suggests that a system may be resilient in more than one way: robust agroecosystems may be able to adapt to climate change even if institutions are weak, while, conversely, strong institutions or the availability of other livelihood options may be available to “rescue” farmers in the event that their fragile agroecosystems collapse. The best situation, of course, is to develop food systems that are situated toward the upper right corner of the cube and are robust in all three dimensions.

CARE has also developed a framework for community-based adaptation as part of their climate change adaptation initiative. The framework is built on four broad strategies for fostering adaptation: 1) building resilient livelihoods, 2) developing local capacity, 3) disaster risk reduction, and 4) tacking the underlying causes of vulnerability. According to the framework, effective adaptation requires addressing each of these needs at three levels: the individual or household level, the local government or community level, and the national level (see Figure A3-3). To help communities and project managers implement this framework, CARE has also designed a participatory process, described in its Climate Vulnerability and Capacity Analysis Handbook (CARE 2009a). In 2010, CARE released two toolkits to guide project design, implementation, and management: the Community-Based Adaptation Toolkit (CARE 2010b) and the Toolkit for Integrating Climate Change Adaptation into Development Projects (CARE 2010c). The negative effects of climate change weigh most heavily on poor communities—and particularly women and marginalized groups within these communities—and the toolkits provide specific guidance on how to increase opportunities for these vulnerable groups to adapt (CARE 2010b).

The general concepts embedded in the “sustainagility ladder,” the “adaptability cube,” and the CARE framework for community-based adaptation can be used to develop a more specific framework for assessing the climate change adaptation benefits of CA in sub-Saharan Africa (see Table A3-1). This framework expands the three broad categories of the adaptability cube (agroecosystems robustness, livelihood options, and institutional capacity) to multiple system domains (e.g., agroecosystem robustness includes land, water, and soils) and then to specific benefits of CA that can support climate change adaptation. The framework focuses disproportionately on agroecosystem robustness because it is the dimension that is typically most actively managed in CA initiatives.

However, the framework also includes the other two dimensions, which are often addressed or affected to at least some degree by CA programs. For instance, CA initiatives may significantly alter the amount and timing of agricultural labor requirements relative to conventional agriculture. These dynamics are very important for rural livelihoods and adaptability given that non-farm income accounts for more than 40% of rural household income in Africa, and, based on experiences from other continents, this percentage is likely to increase over time (Haggblade et al., 2005). Similarly, CA initiatives often include a significant education, extension, and training component, which may help build capacity at the household, local, or district levels.

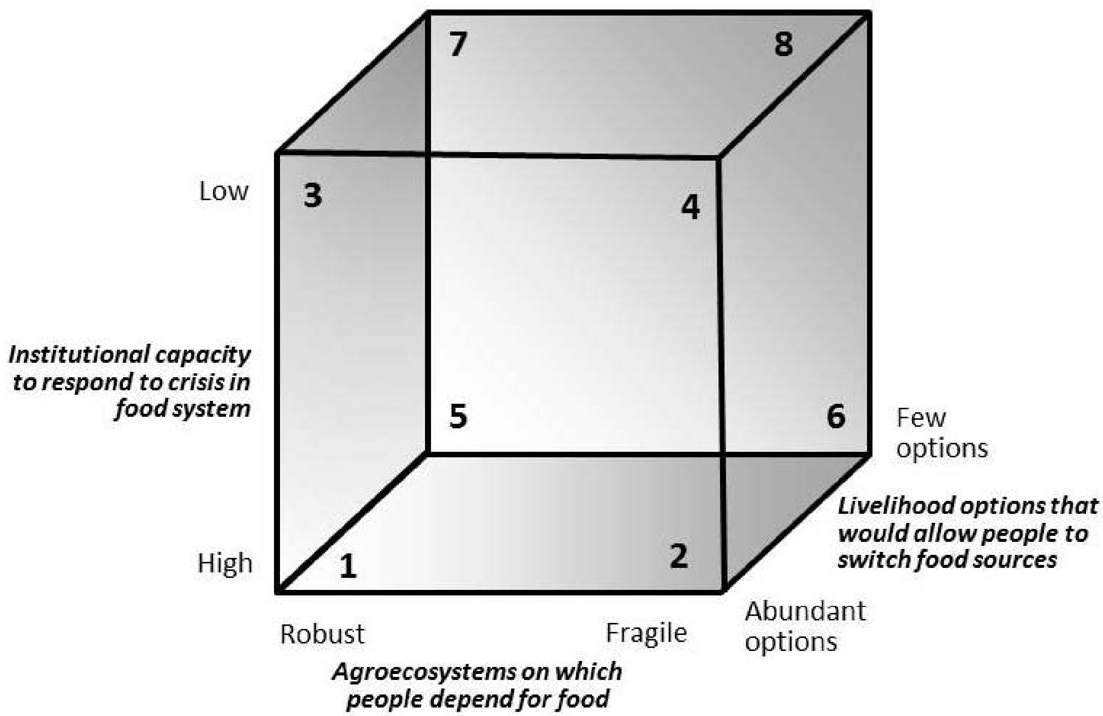

Figure A3-2. "Adaptability cube" illustrating the three key dimensions of the adaptability of food systems: agroecosystem robustness, range of livelihood options, and level of institutional capacity. The most adaptive systems are those in the lower-left of the cube (1), while the most fragile are in the upper right (8). Numbers 2-7 portray systems that have high levels of adaptive capacity in at least one dimension, but not all three. Figure re-drawn from Fraser (2007).

CARE's Framework for Community-Based Adaptation				
	Climate-Resilient Livelihoods	**Disaster Risk Reduction**	**Capacity Development**	**Addressing Underlying Causes of Vulnerability**
National Level	• Government is monitoring, analyzing and disseminating current and future climate information related to livelihoods • Climate change is integrated into relevant sectoral policies • Climate change is integrated into poverty reduction strategy and/or other development policies	• Government is monitoring, analyzing and disseminating disaster risk information • Government is engaged in planning and implementing disaster risk management (including prevention, preparedness, response and recovery) • Functional early warning systems in place • Government has capacity to respond to disasters	• Government has capacity to monitor, analyze and disseminate information on current and future climate risks • Government has mandate to integrate climate change into policies • National policies are rolled out at regional and local levels • Resources are allocated for implementation of adaptation-related policies	• Government recognizes specific vulnerability of women and other marginalized groups to climate change • Policy and implementation is focused on reducing these vulnerabilities • Civil society is involved in planning and implementation of adaptation activities
Local Government/ Community Level	• Local institutions have access to climate information • Local plans or policies support climate-resilient livelihoods • Local government and NGO extension workers understand climate risks and are promoting adaptation strategies	• Local institutions have access to disaster risk information • Local disaster risk management plans being implemented • Functional early warning systems in place • Local government has capacity to respond to disasters	• Local institutions have capacity to monitor, analyze and disseminate information on current and future climate risks • Local institutions have capacity and resources to plan and implement adaptation activities	• Local planning processes are participatory • Women and other marginalized groups have a voice in local planning processes • Local policies provide access to and control over critical livelihoods resources for all
Household/ Individual Level	• People are generating and using climate information for planning • Households are employing climate-resilient agricultural practices • Households have diversified livelihoods, including non-agricultural strategies • People are managing risk by planning for and investing in the future	• Households have protected reserves of food and agricultural inputs • Households have secure shelter • Key assets are protected • People have access to early warnings for climate hazards • People have mobility to escape danger in the event of climate hazardsHos	• Social and economic safety nets are available to households • Financial services are available to households • People have knowledge and skills to employ adaptation strategies • People have access to seasonal forecasts and other climate information	• Men and women are working together to address challenges • Households have control over critical livelihoods resources • Women and other marginalized groups have equal access to information, skills and services • Women and other marginalized groups have equal rights and access to critical livelihoods resources

Figure A3-3. CARE's framework for community-based adaptation. Source: CARE 2009b.

Table A3-1. Adaptation and resilience framework for identifying, characterizing, and assessing benefits that may be associated with CA in sub-Saharan Africa. Attributes in the left column are potential CA benefits that may support climate change adaptation. The right column describes key mechanisms by which each attribute can foster adaptation.

Adaptation category/attribute	Description & potential mechanism for fostering adaptation
A. Agroecosystem robustness	
Land	
1. Higher crop yield per unit area	Increases flexibility in land-use allocation at farm and community levels: more land is available for non-cropping uses Allows food surpluses to be stored, reducing susceptibility to future shortages Reduces pressure for forest clearing, hunting, charcoal production, and other consumptive activities, thus maintaining higher stocks of natural capital
2. More spatially diverse land-use mosaic	Decreases the risk of widespread devastation from crop pests or diseases Maintains stable flows of ecosystem services from complementary land units
Water	
3. Higher water retention and infiltration (lower runoff and evaporative losses)	Reduces the frequency of water non-availability in varying weather conditions Increases crop yields (see #1, above) Maintains higher water table, keeping water in reserve for future use
4. Lower irrigation demand	Allows use of less costly, less complex, and less vulnerable irrigation systems
Soils and Agronomy	
5. Increased temporal diversity of crops (crop rotations)	Reduces vulnerability to catastrophic pest and disease outbreaks
6. Improved fallow management	Increases soil fertility in fallowed areas Provides land and biomass in reserve for emergency use
7. More flexibility in timing of planting	Maximizes crop use of available water, even with erratic rainy seasons Reduces dependence on neighbors for animal traction services
8. Reduced soil erosion	Maintains soil for future use Improves water quality for human and livestock consumption
9. Increased soil fertility from the use of crop residues, cover crops, mulches, and fertilizer trees	Reduces farmers' debt burden associated with chemical fertilizer purchases Reduces susceptibility to price fluctuations in chemical fertilizers Contributes to higher crop yields (see #1, above)
10. Improved soil physical structure, biodiversity, and biotic activity	Increases ecosystem services of soil ecosystem to maintain acceptable ranges of moisture and fertility

Adaptation category/attribute	Description & potential mechanism for fostering adaptation
11. Reduction of weeds	Reduces farmers' debt burden associated with the need to apply herbicides Reduces labor (see #18-20, below)
12. Increased varietal diversity, including drought-tolerant varieties	Increases the likelihood that at least some crops will remain productive despite climate change or extreme climatic events Provides the genetic stock from which to cultivate or domesticate new crops or varieties that may be more productive under a new climate regime, although they may not be high-yielding in the current climate
Energy & Inputs	
13. Fewer seeds needed	Reduces farmers' debt burden associated with seed purchases
14. Less energy (fossil or animal) input required for tillage and weeding	Reduces farmers' debt burden associated with the need to purchase fuel Reduces susceptibility to price fluctuations in fuel
15. More biomass energy sources available from agroecosystems (from agroforests, shelterbelts, etc.)	Increases future options for acquisition of biomass energy sources Reduces labor needed to collect biomass energy Reduces pressure on forests and wildlife habitat, thus maintaining biodiversity and ecosystem services
B. Livelihood options	
Household Livelihoods	
16. Nutritional diversification from increased crop diversity	Improves human health, increasing ability to adapt to future shocks Provides redundancy in the diet such that adequate nutrition can be maintained even if certain crops fail
17. Product diversification	Increases livelihood options Increases the likelihood that at least some products will fetch a high prices, due to de-coupled price cycles of different agricultural and non-agricultural products
Labor	
18. Lower total labor requirement on an annual basis	Increases opportunities for income from additional crops or non-farm labor Reduces susceptibility to "vicious cycle" of disease (HIV, malaria, etc.), labor shortage, and poor nutrition
19. Lower labor requirement for women and children on an annual basis	Allows children to attend school (improving future livelihood options) Allows women to participate in other income-generating activities
20. More seasonal flexibility in labor needs	Increases flexibility to pursue other income options as opportunities arise
C. Institutional capacity	
Human capital and social capital	
21. Improved collaboration between women and men	Increases social capital and overcomes potential barriers to responding to environmental change

Adaptation category/attribute	Description & potential mechanism for fostering adaptation
22. Increased farmer knowledge, innovation, and experimentation	Increases ability to develop sustainable food systems in novel environmental contexts
23. Improved knowledge and extension systems to support sustainable agriculture	Disseminates CA at a larger scale Increases integration of scientific and local/indigenous knowledge systems
24. Increased opportunities for social learning and collective action	Increases capacity for problem-solving, conflict resolution, and development of norms and customs appropriate to novel environmental contexts
Institutional, Policy, and Market Context	
25. More supportive systems for land tenure and resolution of land-use conflict	Reduces conflicts (e.g., between farmers and pastoralists) that can undermine community adaptive capacity Increases incentives to improve natural capital, which can be accessed later
26. Increased access to equipment, seeds, and inputs	Increases farmers' options for plot management
27. Availability of credit and financial services	Allows households to make investments with short-term costs but long-term benefits, including investments to adapt to new climate regimes

Appendix 4: Synthesis of GHG Data from Agroecosystem Components

Table A4-1. Synthesis of data on GHG emissions reduction and/or carbon sequestration for common CA practices as applied in sub-Saharan Africa (expect as noted), or in analogous systems on other continents (as noted).

CA practice	Avoided emissions (tCO_2-eq/ha/yr)	Carbon sequestration		Data source(s)
		(tCO_2-eq/ ha/yr)	C stock (tC/ha) at maturity and (age)	
Tillage and residue management				
Conservation tillage (soil effects)		Variable; often ~0		Nair et al., 2009; Govaerts et al., 2009
		2.1 ± 0.5	Peak reached within 5-10 years	Chivenge et al., 2007
		1.0		GHG Working Group, 2010
		0.18-1.32		Vagen et al., 2005
		0.51		Derpsch, 2005 (cited in Hobbs, 2007)
Conservation tillage (energy & machinery effects)	Up to 60% reduction			Friedrich and Kienzle, 2008
	0.093 (81% reduction)			Erenstein and Laxmi, 2008 cited in Govaerts, 2009
	0.067			Wang and Dalal, 2006 cited in Govaerts, 2009
	0.046			West and Marland, 2002 cited in Govaerts, 2009
	66% fuel reduction			Evers and Agostini, 2001 cited in Robbins, 2004
	Up to 70% reduction			FAO, 2008 cited in Derpsch et al., 2010
No-till plus manure application		0-1.3		Vagen et al., 2005
Manuring		2-5		Li, 1995 cited in ISRIC, 1999

CA practice	Avoided emissions (tCO_2-eq/ha/yr)	Carbon sequestration		Data source(s)
		(tCO_2-eq/ ha/yr)	C stock (tC/ha) at maturity and (age)	
Fertilizer & nutrient management				
Use N-fixing species instead of inorganic N fertilizer	0.04		Variable effects	Authors' estimate[1]
Crop rotations and fallows				
Natural/improved/planted fallows		0.37-19.4		Vagen et al., 2005
Improved fallows in western Kenya (12 months old)			Above: 7-21 Below: 2.7-7.3	Albrecht and Kandji, 2003
Improved fallows in western Kenya (22 months old)			Above: 27-43 Below: 11-19	Albrecht and Kandji, 2003
Crop rotation (general)			11 (9 yrs)	Baker et al., 2007 cited in Derpsch et al., 2010
Lentil and red clover rotation		0.15 ± 0.11		VandenBygaart et al., 2003 cited in Govaerts 2009
Mucuna/maize rotation			15.5 (8 yrs)	Evers and Agostini, 2001 cited in Robbins, 2004
Rotation with vetch			10-17 (13 yrs)	Sisti et al., 2004
Agroforestry				
Live fences/windbreaks		vegetation: 0.59	soil: 24 (8 yrs)	Takimoto et al., 2008 cited in Nair et al., 2009
			20-50 (for 1 m wide fence)	Albrecht and Kandji, 2003
Hedgerow intercropping / alley cropping			6-10	Albrecht and Kandji, 2003
Fodder bank, Mali			0.29 (7.5 yrs)	Takimoto et al., 2008 cited in Nair et al., 2009
Live fence, Mali			0.59 (8 yrs)	Takimoto et al., 2008 cited in Nair et al., 2009
Parklands, Mali			1.09 (35 yrs)	Takimoto et al., 2008 cited in Nair et al., 2009

CA practice	Avoided emissions (tCO_2-eq/ha/yr)	Carbon sequestration		Data source(s)
		(tCO_2-eq/ ha/yr)	C stock (tC/ha) at maturity and (age)	
Agrisilviculture, India			1.26 (5 yrs)	Swamy and Puri, 2005 cited in Nair et al., 2009
Silvopastoralism, India			1.37 (6 yrs)	Kaur et al., 2002 cited in Nair et al., 2009
Silvopastoralism, India			6.55 (5 yrs)	Kumar et al., 1998 cited in Nair et al., 2009
Cacao agroforests, Cameroon			5.85 (26 yrs)	Duguma et al., 2001 cited in nair et al., 2009
Cacao agroforests, Costa Rica			11.08 (10 yrs)	Beer et al., 1990 cited in Nair et al., 2009
Shaded coffee, Togo			6.31 (13 yrs)	Dossa et al., 2008 cited in Nair et al., 2009
Agroforestry woodlots, Puerto Rico			12.04 (4 yrs)	Parrotta, 1999, cited in Nair et al., 2009
Agroforestry woodlots, India			6.53 (9 yrs)	Kumar et al., 1998 cited in Nair et al., 2009
Homegardens, Indonesia			8.00 (13 yrs)	Roshetko et al., 2002 cited in Nair et al., 2009
Mixed species stands, Puerto Rico			15.21 (4 yrs)	Parrotta, 1999, cited in Nair et al., 2009
Reduced deforestation and forest degradation				
Tropical equatorial forest in sub-Saharan Africa			99-200[2]	Gibbs and Brown, 2007 and IPCC, 2006 cited in Gibbs et al., 2007
Tropical seasonal forest in sub-Saharan Africa			38-152[2]	Gibbs and Brown, 2007 and IPCC, 2006 cited in Gibbs et al., 2007
Tropical dry forest in sub-Saharan Africa			17-72[2]	Gibbs and Brown, 2007 and IPCC, 2006 cited in Gibbs et al., 2007
Open forest in sub-Saharan Africa			30-36[2]	Several papers cited in Gibbs et al., 2007

CA practice	Avoided emissions (tCO_2-eq/ha/yr)	Carbon sequestration		Data source(s)
		(tCO_2-eq/ ha/yr)	C stock (tC/ha) at maturity and (age)	
Protection of savannas from annual burning (on clay soils in SW Zimbabwe): for soil C only, annually for 50 yrs	0.73			Bird et al., 2007 cited in Vagen et al., 2005
Protection of dambo grassland from annual burning (Western Province, Zambia)			0.5 (1 yr)[3]	Hoffa et al., 1999
Protection of miombo woodland from annual burning (Western Province, Zambia)			2.1 (1 yr)[3]	Hoffa et al., 1999
Entire farming/land-use systems (illustrative examples)				
Maize, crop residues composted and used as mulch; fruit and fuel trees (western Kenya)		2.1		Forest Trends et al., 2010
Gliricidia-maize intercropping (Malawi)			123–149 in soil	Makumba et al. 2006
Conservation tillage plus crop rotations and cover crops		1.9		Franzluebbers, 2005 cited in GHG Working Group 2010
Increase tree cover plus composting (coffee systems)		1.8		Forest Trends 2010

[1] Assumes a 40% reduction in application of inorganic N fertilizer due to adoption of CA practices (Derpsch et al., 2010), a baseline fertilizer application rate of 50 kg N/ha/yr (close to the target rate under fertilizer subsidy programs such as those in Malawi), and a GHG footprint of urea N fertilizer of 2 kg CO_2-eq per kg N (Wood and Cowie, 2004). Given that smallholder fertilizer rates in Africa average closer to 8 kg N/ha/yr, the estimate provided here is an optimistic assessment of this component of avoided emissions.

[2] Net avoided deforestation equals this value minus the carbon stock of the alternative “business as usual” agricultural scenario, which is likely to have a small, but non-zero, carbon stock.

[3] Time-averaged net reduction in carbon stock, assuming that grass biomass is reduced by 1.05 t/ha dry matter for danbo and 4,167 t/ha dry matter for miombo as a result of annual fires, and that this biomass regenerates to its prior level during the growing season.