Is Climate-Smart Agriculture effective?

A review of selected cases

Working Paper No. 129

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

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Abstract

Climate-Smart Agriculture (CSA) is an approach to address the interlinked challenges of food security and climate change, and has three objectives: (1) sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development; (2) adapting and building resilience of agricultural and food security systems to climate change at multiple levels; and (3) reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries). This paper examines 19 CSA case studies, to assess their effectiveness in achieving the stated objectives of CSA, while also assessing other co-benefits, economic costs and benefits, barriers to adoption, success factors, and gender and social inclusion issues. The analysis concludes that CSA interventions can be highly effective, achieving the three CSA objectives, while also generating additional benefits in a cost-effective and inclusive manner. However, this depends on context specific project design and implementation, for which institutional capacity is key. The paper also identifies serious gaps in data availability and comparability, which restricts further analysis.

Keywords

Climate-Smart Agriculture; adaptation; resilience; mitigation; effectiveness; cost-benefit analysis

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Contents

Acronyms

ACSAA	African Climate-Smart Agriculture Alliance
ALVs	African Leafy Vegetables
APC	Colombia’s Presidential Agency for International Cooperation
ARC	African Risk Capacity Facility
AWD	Alternate Wetting and Drying
CBI	Coffee-Banana Intercropping
CCAFS	CGIAR Research Program on Climate Change, Agriculture, and Food Security
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CORPOICA	Colombian Corporation for Agricultural Research
CSA	Climate-Smart Agriculture
CSOs	Civil Society Organisations
EADD	The East Africa Dairy Development Project
EGSP	Effective Grain Storage Project
FAO	Food and Agriculture Organisation of the United Nations
FHH	Female-headed household

FMNR	Farmer-managed natural regeneration
GACSA	Global Alliance for Climate Smart Agriculture
GHG	Greenhouse Gas Emissions
HABP	Household Asset Building Programme
IDEAM	Colombian National Institute of Hydrology, Meteorology, and Environmental Studies
IFAD	International Fund for Agricultural Development
IGP	Indo-Gangetic Plain
IRR	Internal Rate of Return
LLL	Laser-Assisted Precision Land Levelling
MADR	Colombian Ministry of Agriculture and Rural Development
MEFCCA	Ministry of Family, Community, Cooperative and Associative Economy
NAMA	Nationally Appropriate Mitigation Action
NARS	National Agricultural Research Systems
NICADAPTA	Adapting to Markets and Climate Change Project in Nicaragua
NGO	Non-governmental Organization
PES	Payment for Ecosystem Services
PSNP	Productive Safety Net Programme
RFM	Risk Financing Mechanism
RISEMP	Regional Integrated Silvopastoral Ecosystem Management Project

1. Introduction

Climate change impacts, together with increasing food demand, poses risks to global food security (IPCC 2014). These impacts are deepening the problems already being faced by smallholder farmers in developing countries, who are the most vulnerable to climate change (Campbell and Thornton 2014 p. 3), but produce 70% of the world's food needs (FAO 2013). Over the last few decades, agricultural productivity has been low and stagnant, particilarly in smallholder production systems (FAO 2015 p. 1). In some cases productivity has already started declining due to changing rainfall patterns, and increasing frequency of extreme events such as droughts and floods (Lipper et al. 2014 p. 1068). As a result of climate change, yields for key food crops such as maize and wheat have already reduced by an estimated 3.8% and 5.5% respectively, relative to a counterfactual without climate trends (Lipper et al. 2014 p. 1068). The potential contribution of agriculture as a pathway out of poverty for millions of poor rural families is at risk. Smallholder farmers are the most vulnerable population to the changing climate as they lack financial, technical and political means to support adaptation efforts. Without access to information, technology, markets, financing, institutional support and decision making opportunities, smallholder farmers are powerless to respond to the challenges brought by a changing climate.

It is in this context that the concept of Climate-Smart Agriculture (CSA) becomes relevant. The concept builds on the longstanding goal of development through sustainable agriculture by recognising both the growing need for agricultural systems to adapt to progressively changing climates, and the coincident necessity that the sector takes action to mitigate emissions (Lipper et al. 2014). In the context of landscapes and food systems, the original definition of CSA adopted by FAO refers to three objectives: (1) sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development; (2) adapting to and building resilience to climate change at multiple levels (from farm to national); and (3) reducing or removing greenhouse gas emissions from agricultural activities across landscapes, livestock and fisheries. CSA is an approach that aims to achieve different combinations of these objectives relevant to the local context. It can be applied at various levels (farm, landscapes, and food systems) and incorporates technologies and practices, as well as policies, institutions, and investments.

The three objectives of CSA may be synergistic or involve trade-offs, depending on the local context. For example, synergies between adaptation and productivity occur in the Drought Tolerant Maize for Africa initiative, where 100 new drought-tolerant maize varieties and hybrids were developed and released across 13 countries in Africa, which led to farmers reporting increased yields of up to 20–30% under moderate drought conditions (Cooper et al. 2013). These drought resistant varieties allow farmers to adapt to the changing climate, since projections indicate that ~90 % of currently cropped maize area in Africa will experience negative impacts, with a 12-40% reduction in yields by the end of the 21st century, if no adaptation actions are taken (Ramirez-Villegas and Thornton 2015). On the other hand, subsidised fertiliser in the miombo woodland regions of Southern Africa may increase productivity and food security (Denning et al. 2009 p. 9), but the trade-off may be increased deforestation (Dewees et al. 2010 p. 42), thus driving up emissions. A recent review by Cooper et al. (2013) of the evidence base for successful and ambitious interventions within the agriculture sector has shown how the trade-offs can be avoided in the near term, and over limited spatial scale. Even if actions cannot deliver on all fronts in all contexts, the CSA concept is still applicable (Lipper et al. 2014 p. 1069). Of greater importance is that all three CSA objectives are considered across different scales and time horizons to arrive at solutions tailored to the local context. Accordingly, this allows for the relative importance of each objective to vary across locations and situations. Flexibility of the CSA approach in the face of trade-offs is particularly important in developing countries, where agricultural growth and adaptation for food security and economic growth are a priority, and where poor farmers are the most affected by—but have contributed least to—climate change.

CSA has gained considerable interest in recent years and a range of actors have initiated CSA actions, including farmers, governments, Civil Society Organizations (CSOs), international organizations, private sector, and the research community. The Global Alliance for Climate Smart Agriculture (GACSA) was launched as a collaborative platform for action for these diverse actors at the UN Secretary General's Climate Summit in September 2014. Regional alliances are also being formed to support CSA action at the regional level, and include the Africa Climate-Smart Agriculture Alliance (ACSAA), which aims to reach 25 million farmers by 2025, and the North American Climate-Smart Agriculture Alliance. While these actions aim to achieve the goal of food security under a changing climate, sceptics have questioned whether CSA brings anything new or actually yields the stated socio-economic and environmental gains (Anderson 2014).

This paper examines whether CSA as currently implemented provides answers to the challenges being faced by farmers as a result of a changing climate, and achieves its stated objectives in a cost-effective manner. We also attempt to identify the additional co-benefits delivered by CSA interventions, and their approach to addressing gender and social inequalities. The barriers to adoption of CSA interventions and key success factors are also examined.

2. Methods

Case selection

This paper analyses 19 case studies of CSA interventions using a common framework. Based on this analysis, results related to the criteria are presented in Section 3.
The primary sources from which cases were identified are listed in Appendix II. The main focus was the CCAFS portfolio and potential cases were identified through the CCAFS Planning and Reporting platform (technical reporting platform of program participants), and email requests to research leaders. In order to address gaps in sectoral and regional coverage, additional cases were identified through a search of published literature.

The CCAFS portfolio comprises numerous projects and interventions, carried out by different CGIAR centres and partners. Generally, projects share the common goals of reducing rural poverty, increasing food security, and ensuring sustainable management of natural resources. These projects are typically monitored and reported during the course of implementation, and reported upon following project completion. The reporting outputs are typically made available to the public and/or institutions in the form of webpages, working papers, reports and publications within academic journals. The form and level of detail of this reporting varies considerably between projects (e.g. depending on stage of implementation), ranging from in-depth analysis of randomised control field trials to simple communication of a projects activities via a webpage or blog post. However, most reporting refers to a key CCAFS source document, and care was taken to track down the most authoritative and information-rich source in each case.

A total of 58 potential cases were identified. These cases were screened based on availability and depth of supporting information in relation to the framework, and to ensure balanced representation of different types of interventions and regions, giving 19 cases in the final analysis. Table 1 lists the different types of shortlisted cases, and Table 2 provides summaries of these cases.

Table 1 Types of shortlisted cases

Categories	No. of cases
Crops (interventions focused on grains, fruits, plants, etc.)	4
Fisheries (interventions focused on aquaculture or marine fisheries)	2
Landscapes (interventions that take into account the broader landscapes within which agricultural production takes place)	2
Livestock (interventions focused on cattle, poultry, etc.)	2
Policies and Programs (government-led interventions which seek to implement CSA at scale)	3
Services (interventions including climate information services, index-based insurance, etc., which help farmers adopt CSA practices or improve their financial security)	3
Value chains (CSA interventions within the full range of value-adding activities that transform an agricultural good from post-harvest to final product marketed to consumers)	3

Table 2 Description of cases

Case	Description	Category
Laser-Assisted Precision Land Levelling (LLL) in India	LLL involves the use of laser technology to efficiently achieve a flat even soil surface, generating better yields with less inputs. Introduced in 2011, LLL is now applied on an estimated 500,000 hectares across the state of Haryana, India.	Crops
Alternate Wetting and Drying (AWD) in Vietnam and Bangladesh	AWD is a rice management technique involving periodic drying and re-flooding of rice fields, reducing water inputs and emissions, while maintaining yields.	Crops
Coffee-Banana Intercropping (CBI) in East Africa	By growing coffee and bananas together, coffee farmers in East Africa reduce their vulnerability to climate change impacts, while generating additional income and food security through diversification.	Crops
GreenSeeker technology for better nitrogen management in India and México	GreenSeeker is a site-specific nutrient management tool allowing for more precise and efficient use of fertilizers, improving yields while reducing input requirements.	Crops
Aquaculture in the Mekong River Delta	Several CSA measures, such as relocation, reinforced dykes and salinity tolerant species are being adopted by aquaculturists in the Mekong river delta to increase climate change resilience, while enhancing mitigation and productivity.	Fisheries
Fish Ring Microhabitats in Bangladesh's Rice Fields	By placing simple concrete rings in rice fields, farmers in Bangladesh create microhabitats for fish that are brought into flooded fields during the monsoon season. Allowing the fish to survive and thrive in the rings provides an additional source of food and income.	Fisheries
Farmer-Managed Natural Regeneration (FMNR) in Niger	Since the 1980s, farmers in Niger have been using the FMNR technique to regenerate over 5 million hectares of degraded lands, increasing yields, wood-based income sources, and carbon sequestration.	Landscapes

Loess Plateau Watershed Rehabilitation Project	By incorporating improved farming practices and tree planting, the Loess Plateau watershed rehabilitation project has benefitted over 2 million hectares of degraded lands, while bringing 2.5 million households out of poverty.	Landscapes
East Africa Dairy Development (EADD) Project	Since 2008, the EADD project has improved dairy productivity in East Africa through the dissemination of a variety of practices, such as improved livestock feeding and breeding. The first phase of the project earned local farming families over USD 131 million.	Livestock
Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)	Between 2002-2007, RISEMP brought silvopastoral practices to Costa Rica, Colombia and Nicaragua. In addition to rehabilitating overgrazed lands, the program brought mitigation and productivity benefits to participating farmers.	Livestock
Productive Safety Net Programme (PSNP) in Ethiopia	The Government of Ethiopia launched the PSNP in 2005, to provide transfers of cash or food to food insecure people, who in turn receive employment in public works projects.	Policies and Programs
National Agroforestry Policy of India	In 2014, the Government of India launched the world's first National Agroforestry Policy, aimed at mainstreaming the incorporation of trees and shrubs into farmlands. This policy increases carbon sequestration through increased tree coverage, while enhancing productivity through improved soil fertility and also increases resilience to climate impacts.	Policies and Programs
Climate and the Colombian Agriculture Sector: Adaptation for a Productive Sustainability	Launched in 2012, this Agreement seeks to strengthen the resilience of agriculture and livestock to climate variability and change and improve the efficiency of resource use in production systems in priority regions in Colombia through 4 components: i) Modelling and agroclimatic forecasts; ii) Climate-Site Specific Management; iii) Technological options for adaptation in priority crops; and iv) Environmentally sustainable production systems.	Policies and Programs
Climate seasonal forecasts within the cowpea sector Burkina Faso	Seasonal forecasts help cowpea farmers in Burkina Faso understand, monitor and predict climate variability, leading to better yields and resilience to climate variability.	Services
Communicating seasonal forecasts to farmers in Senegal for better agricultural management	Since 2011, climate information services have been broadcasted to millions of farmers in Senegal, using simple to understand forecasts. By providing relevant and comprehensible climate information, farmers are more capable of coping with increasing climate uncertainty.	Services
African Risk Capacity (ARC) Facility	The ARC Facility reduces the time lag in system responses to food crises. By creating a pan-African insurance safety net based on weather indices, governments can quickly and efficiently intervene when crisis strikes, to avoid food insecurity and agricultural asset loss.	Services
Effective Grain Storage Project (EGSP)	By using hermetically sealed metal silos, farmers protect their harvests from pests and disease. The project reduces post-harvest losses and improves farmer productivity and resilience through improved grain storage.	Value chains
African Leafy Vegetables (ALV)	The ALV programme ran from 1996-2004 and brought nutritious and hardy African Leafy Vegetables into mainstream consumption once again, delivering nutritional benefits to consumers, and poverty alleviation benefits to its farmers.	Value chains
Adapting to Markets and Climate Change Project in Nicaragua (NICADAPTA)	Launched in 2014, the NICADAPTA project provides investment opportunities, training, and technical assistance to approximately 100,000 smallholder farmers. Nicaragua's agricultural sector is highly sensitive to climate variations, and NICADAPTA aims to help farmers climate-proof their production, while reducing emissions by over 2 million tonnes of CO_2e.	Value chains

Some of the shortlisted cases used in this study explicitly aim to achieve one or more of the CSA objectives. Others implicitly address these goals but are not intentionally aligned with the CSA paradigm, whereas other cases are only indirectly related to the CSA concept. Indeed, many cases were initiated before the CSA concept came to light, but are now regarded as part of CSA and provide useful insights. In the case selection process, we have endeavoured to select a set of cases balanced across sectors and regions, while having sufficient information to allow meaningful analysis on effectiveness, and for identifying success factors and barriers for adoption.

A key consideration in a robust assessment of the impact of a given intervention is the availability of information on a counterfactual situation, i.e. information on beneficiaries with the intervention and those same beneficiaries without the intervention. In practice, this is accomplished using a comparable control group or by making comparison to a prior or 'baseline' situation. In theory, differences in outcomes between the groups can then be attributed to the intervention (Winters et al. 2010). The CSA cases considered in this study do not always make the study design explicit, nor define which counterfactual situation costs/benefits are being evaluated against. Most commonly, the cost and benefits, whether in terms of yield change, adoption rates, etc, are stated relative to the situation prior to the intervention. Depending on the experimental design, varying degrees of accuracy in terms of the cause-effect relationship between the intervention and a specific outcome can be obtained. In this study, it is assumed that outcomes relevant to CSA objectives in the selected cases are attributable to the intervention.

This concern regarding evaluation design will be partly addressed in a forthcoming review by Rosenstock et al. In their study, a large meta-analysis shall be conducted, making use of comprehensive search strings to mine databases of peer reviewed literature. The results shall then be screened such that only literature that contains primary data and a comparison of a CSA to a conventional or baseline practice is considered.

Analytical approach

We used a common framework to assess effectiveness across CSA interventions. The framework consisted of six criteria:

i. CSA benefits (Productivity, resilience, and mitigation)

This criterion examined the contribution of each intervention to the three objectives of CSA i.e. (1) sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development; (2) adapting to and building resilience to climate change at multiple levels (from farm to national); and (3) reducing or removing greenhouse gas emissions from agricultural activities across landscapes, livestock and fisheries. For each objective, quantitative outcome metrics are presented where available and qualitative information is included to demonstrate the context and conditions in which projects have proved effective.

ii. *Other co-benefits*

Other benefits accrued by these interventions, but which do not directly contribute to CSA objectives were examined here. These include other livelihood benefits, health benefits etc, achieved through the intervention. While these benefits do not address CSA objectives, they may influence adoption decisions.

iii. *Economic costs and benefits*

This criterion examined economic costs and benefits of interventions, with the view of assessing cost effectiveness of interventions. Data including cost-benefit ratios and internal rates of return have been considered under this criterion.

iv. *Barriers to adoption*

Factors that hamper implementation of CSA interventions, in general or for specific locations have been considered.

v. *Key success factors*

Under this criterion, we considered the factors that were responsible for the intervention's success, with a view of generating lessons for CSA implementation and scale up. Success factors may be general such as creation of incentive schemes, or local such as specific stakeholder engagement approaches.

vi. *Gender and social inequality*

The role of CSA in addressing gender gaps (Vermeulen 2015) has been studied. Under this criterion, we considered how individual interventions address gender and social inequality issues and accrue benefits to women and disadvantaged groups.

3. Results

CSA Benefits

Of the 19 cases analysed, all of them contributed towards sustainably increasing agricultural productivity, and related increases in farm incomes, food security and development. Seemingly, the primary focus of the cases studies included in this study is increasing productivity. Most cases provided clear indications of yield or income gains derived per hectare in comparison to scenarios without CSA interventions.

Eighteen cases helped build resilience of agricultural and food security systems to climate change, and for farmers adapt to climate change. Only 15 cases clearly contributed to reducing greenhouse gases from agriculture. Fourteen of the cases were achieving triple wins by contributing to all three CSA objectives (Table 2). However, in some of these triple-win cases, only minor or indirect mitigation benefits were observed, and these were not clearly quantified. For instance, while over 5 million hectares of land was covered with trees and aboveground biomass as a result of the Farmer-Managed Natural Regeneration (FMNR) program, systematic data regarding the mitigation impact is lacking although a net positive mitigation benefit is expected. Lack of robust measurements was also observed in cases' contributions to increasing resilience and adaptation. This is not unexpected since contributions towards this objective are complex and a number of factors are at play. There is no existing standard to measure adaptation benefits at program or national level yet. For example, the enhanced biodiversity through increased cultivation of African Leafy Vegetables (ALVs) has in all likelihood had positive impacts on resilience and adaptation at multiple scales, but these benefits have not been quantified. Notably, many of the resilience benefits were directly linked to productivity gains, where surplus food or better incomes would provide safety nets, minimising the impact of leaner harvests due to drought, extreme weather events etc. This was observed in the cases on seasonal forecasts in Senegal and Colombia, as well as in FMNR in Niger, where productivity gains increased resilience of farmers to adverse climate impacts.

Case analysis also revealed that not many cases work at different scales in order to implement and scale out and up CSA, including the conversation between the local and the national level through innovative policy and financial actions. An exception is the Climate and the Colombian Agriculture Sector: Adaptation for a Productive Sustainability case, which tries to connect experimental studies and work with communities at the local level to policy formulation at the national level.

Table 3 Contributions of cases towards CSA objectives

Case	Productivity	Resilience	Mitigation
LLL in India	✓	✓	✓
AWD in Vietnam and Bangladesh	✓	✓	✓
CBI in East Africa	✓	✓	✓
GreenSeeker technology for better nitrogen management in India and México	✓		✓
Aquaculture in the Mekong River Delta	✓	✓	✓
Fish Ring Microhabitats in Bangladesh's Rice Fields	✓	✓	
FMNR	✓	✓	✓
Loess Plateau Watershed Rehabilitation Project	✓	✓	✓
EADD Project	✓	✓	✓
RISEMP	✓	✓	✓
PSNP in Ethiopia	✓	✓	✓
National Agroforestry Policy of India	✓	✓	✓
Climate and the Colombian Agriculture Sector: Adaptation for a Productive Sustainability	✓	✓	✓
Climate seasonal forecasts within the cowpea sector in Burkina Faso	✓	✓	
Communicating seasonal forecasts to farmers in Senegal for better agricultural management	✓	✓	
ARC Facility	✓	✓	
EGSP	✓	✓	✓
ALVs	✓	✓	✓
NICADAPTA	✓	✓	✓

Other co-benefits

In addition to contributing to CSA objectives, interventions also realised a wide range of co-benefits. Job creation was the most common co-benefit generated by CSA interventions. In some cases, such as the EGSP and LLL, this benefit was related to the increased demand for manufactured goods, such as metal sheets for building silos, and advanced farming technology. On the other hand, more efficient farming practices such as in the Loess Plateau watershed rehabilitation project meant that farmers had time to pursue additional employment opportunities off farm.

Another commonly cited co-benefit was the establishment of public infrastructure as a result of CSA interventions. These included roads, which allow farmers to easily transport their goods to marketplaces, as well as granting better access to education and healthcare. Institutional capacity, an important pre-requisite to effectively implementing CSA interventions, was also found to have been strengthened through several interventions. In the Colombian case, the strengthening of institutional capacities among the government and farmers' associations was a co-benefit of the project but at the same time was a key determinant to scale up the implementation of CSA practices in the country. Social, human and financial capital was also developed among farmers participating in several of the projects. For example, stronger community ties were created due to ALV cooperatives, which reduced moral hazard, and improved service delivery. Farmers involved with the project also developed their business skills in addition to their farming practices. Improving the skills and organisation of farmers allowed them to attract micro-finance credit and start their own savings schemes.

Nutritional and health benefits were also provided by some CSA interventions, including FMNR and ALVs. FMNR increases the number of trees, providing health benefits by growing additional nutritional fruits, as well as creating a supply of medicinal leaves. By mainstreaming ALVs, which are filled with vitamins and micronutrients, a cheap and abundant source of healthy foods was established.

Economic costs and benefits

Cases (Appendix I) with cost-benefit data available demonstrate healthy rates of return and cost-benefit ratios (Table 4). However, these cost-benefit calculations do not take the full range of CSA benefits into account. These calculations are largely based on generic benefits such as reduction of input costs, increase in income, reduction of losses etc. There have been limited efforts to value CSA benefits such as increased resilience or sequestration of greenhouse gas emissions. Valuing these benefits would give a more accurate understanding of cost-effectiveness of these projects. For example, in the Loess Plateau watershed rehabilitation case, it was estimated that the economic/ecological benefit of the increase in soil organic matter alone was approximately USD 2.6 million in a single county (Shi and Wang 2011 p. 15765). Overlooking such benefits will limit analysis of cost-effectiveness of CSA interventions.

The cases indicate that the economic performance of interventions depend on scale and context. For example, the Laser-Assisted Precision Land Levelling (LLL) and Effective Grain Storage Project (EGSP) interventions are not cost-effective at smaller scales due to high upfront costs; larger scale operations are required to achieve economies of scale.

Data gaps in some cases, and the absence of comparable cost-benefit calculations makes it difficult to compare across cases and arrive at overarching messages on cost-effectiveness of CSA. In some cases, the economic benefits will only materialise in the long term, and long-term monitoring of costs and benefits is required to conduct ex-post analysis. Robust cost-benefit calculations for a wider range of CSA interventions will aid decision makers in choosing the most appropriate intervention in a specific context.

Barriers to adoption

In spite of positive cost-benefit calculations, high initial investment costs of CSA technologies and practices were found to be a key barrier for adoption. For technological interventions such as LLL, GreenSeeker, EGSP and fish rings, these costs could serve as a disincentive for farmers. In such cases, economic incentives that allow farmers to meet the initial investments are effective for increasing adoption rates. Stakeholder engagement and communicating the long-term benefits is also an effective approach.

Low institutional capacity was also identified as a barrier for CSA implementation, and so investments in institutional strengthening should precede or coincide with interventions. In the NICADAPTA case, investments are specifically targeted at building institutional capacities in Nicaragua. Limited or mis-directed government support and counter-intuitive policies was also found to be a barrier, such as the case of FMNR, where the government recommendation during the early 1980s was for farmers to plough tree stumps. This indicates the dual need for policies to be (a) informed by the latest science, and (b) to create an enabling environment for CSA action. CSA project design should also take stock of the policy environment and be aligned with it.

Another important barrier for implementation, especially at the local level, is the language used by scientists to transmit key messages in relation to the research they are generating. This is the case of the Colombian project where the language of the agroclimatic newsletters shared with farmers at the beginning of the project was too technical to generate an impact in terms of supporting decision making processes of these farmers.

Key success factors

As high upfront costs are a significant barrier for adoption of CSA, the key for success is to find innovative ways of overcoming these barriers. For example, in the GreenSeeker and LLL cases, innovative forms of social organization and cost-sharing helped overcome diseconomies of scale. In some cases, such as LLL, the presence of government subsidies helped drive farmer adoption in the initial phases of the project. In the RISEM case, the Payments for Ecosystem Services (PES) were key for the success of the project.

Outreach and extension support, as well as community engagement, is a success factor in multiple cases. For example, in the climate information services cases, incorporating indigenous knowledge within advisories and creating an interactive format helped build the user-base. In these cases, co-production with climate information users also helped identify the most effective and relevant forms of communication. While community training and capacity enhancement can kick-start adoption in the short-run, the EGSP, ALV and Colombian cases indicate that market access and private sector involvement are important to scale up CSA interventions in the long-run. Especially important, as demonstrated in the Colombian case, is the involvement of these key stakeholders from the very beginning of the project so that they feel ownership of the results and knowledge that is being generated. In places where data availability is still a constraint to generate knowledge around CSA practices, credibility with data owners must be gained in order to encourage them to share more information.

Gender and social inequality

While addressing gender and social inequality does not appear to be the primary objective of the case studies analysed, 13 cases provide direct and/or indirect benefits to women and vulnerable groups. These benefits included employment opportunities and increased access to resources. For example, through the FMNR project, women received increased access to wood products and medicinal plants, improving their incomes and allowing them to invest in assets such as livestock. However, in the case of PSNP, the programme may actually have provided additional challenges for women rather than providing support. Although PSNP provides relief for food-insecure households, this aid was conditional, based on participation in public works programmes. For some women, it became difficult to navigate their daily household obligations while simultaneously having to work. The cases indicate that it is possible to ensure that CSA interventions deliver benefits to women and vulnerable groups, if this outcome is considered in program design.

Table 4 Overview of costs, benefits, barriers to adoption, success factors and gender benefits across cases

	Economic costs and benefits	Barriers to adoption	Key success factors	Gender and social inequality
LLL in India	IRR from 50% to 120% depending on various factors.	High upfront cost. Works best on larger plots.	Ensuring commercial profitability. Government subsidies. Social organization for small-scale farmers.	Improves job opportunities for women.
AWD in Vietnam and Bangladesh	Bangladesh: 8-39% increase in profits. Vietnam: 17-41% increase in profits.	High transaction costs for farmers when evaluating how to implement AWD. Lack of effective scientific communication and awareness of evidence of AWD success at the local level.	Outreach and extension. Targeting regions with high irrigation costs and yield gaps. Correct timing of intervention.	Limited role for women farmers in implementation.
CBI in East Africa	CBI generates 50% more revenue than mono-cropping.	High upfront capital and labour costs.	CBI benefits can be optimized through e.g. improved soil management and optimal planting arrangements. Special training required to strike balance between coffee and banana crops.	Women contribute significantly to coffee production, but there are imbalances in terms of plantation ownership.
Using GreenSeeker technology for better nitrogen management in India and México	Costs USD 550. Reduces input costs. Increases in yields.	High up front cost. Some training is required.	Addressing low penetration rates. Tax relief, subsidy programs and other actions to lower upfront costs.	None
Aquaculture in the Mekong River Delta	Short-term costs of non-adaptation are high, due to tight margins for fisherfolk. Planned infrastructure adaptation measures for catfish farms will total approximately USD 191 million between 2010-2020.	Lack of education. Little income dependency on aquaculture. Lack of land ownership.	Ministry of Agriculture and Development's development plan, implementing the necessary adaptation measures. Coordination efforts with neighbouring countries who share resources.	None
Fish Ring Microhabitats in Bangladesh's Rice Fields	Fish rings bring additional income from 1.5-2kg of fish per year. Cost of construction is USD 11.5.	Initial investment cost. Using fish rings as fish traps will not allow fish to survive and breed. Some locations are not suited for fish rings.	Must be placed and marked properly. Community-based management can prevent poaching.	None
FMNR in Niger	IRR of 31%. Taking into account all factors, FMNR brings USD 56/ha in benefits per year.	Lack of knowledge. Counter-intuitive government policy.	Farmer to farmer knowledge sharing and community groups. Pre-existence of social capital.	Women may have benefitted the most from FMNR.
Loess Plateau Watershed Rehabilitation Project	Degradation of Loess Plateau cost USD 1.28 billion in lost potential. Overall economic rates of return from 18%-21%.	Must ensure re-employment of surplus labour. Farmers may not reap benefits in the short-term.	Terracing provided many benefits, but required further development of infrastructure.	Significant increase in employment rates of women.

EADD Project	Farmer earnings increased 50% per litre of milk compared to 2008.	Lack of knowledge. Additional labour needs. Commercial feed and livestock genetic improvement is resource heavy.	Knowledge sharing through dairy producer associations. Training and awareness creation to drive uptake of several project components.	Phase II has the goal of increasing number of women supplying milk by 30%
RISEMP	At the end of the project, 14%-37% IRR depending on the silvopastoral practices adopted, as well as existence of PES schemes.	High initial labour and capital investment costs. Most environmentally beneficial practices may not be the most economically attractive for farmers. Risk of perverse incentives.	Empowering farmers to become the voice of the project. Developing appropriate CSA indicators which could be understood by farmers. Small upfront payments to incentivize adoption.	None
PSNP in Ethiopia	Cost per beneficiary of USD 47. More households have an improved economic condition. Average of 1.8 cost-benefit ratio for public works programme.	Difficult for women to balance household tasks with work. Time lag in early warning data. Overly restrictive population coverage.	Ensuring quality and sustainability of public works projects.	Efforts taken to accommodate women and their domestic responsibilities. Women make up 25%-50% of beneficiaries.
National Agroforestry Policy of India	USD 30-40 million investment.	Constraining legal environment. Farmers may be hesitant to reduce growing area.	Cooperation and coordination between and within government and NGO partners. Providing portfolios of activities for farmers. Finance and insurance schemes.	None
Climate and the Colombian Agriculture Sector: Adaptation for a Productive Sustainability	Seeks to avoid 30% of total losses (USD50 million) in crops such as rice and maize due to climate variability. Production gap is expected to be reduced by at least 50%, saving resources equivalent to investments used to feed about 4 million of Colombian population.	To gain credibility with national farmers' organizations. Limited reach of national farmers' organizations. The language of the agroclimatic newsletters needs to be adjusted for the specific audiences.	Articulation since the very beginning of the project with relevant stakeholders in the agricultural sector. Alliances with public and private institutions. Simplifying language to local understanding of agroclimatic newsletters in order to bridge the gap between meteorologists, agronomists, modellers and practitioners.	None
Climate seasonal forecasts within the cowpea sector in Burkina Faso	Higher yields at lower costs. Added value for cowpea (USD 30/ha).	Forecasts must correspond to needs of farmers. Alternate management options must be available. Forecasts must be properly communicated.	Clear understanding of factors that limit access. Participatory and interactive approaches.	The project intends to address the needs of women.
Communicating seasonal forecasts to farmers in Senegal for better agricultural management	Large number of people who have access to climate information (about 4 million people) indicates implicit cost-effectiveness.	Communicating complex aspects of seasonal forecasts to farmers. Lack of access to land is a constraint, especially for women.	Partnerships with meteorological agencies, ministries and local radio stations. Community engagement and interactive broadcasts.	The program found that men and women access climate information differently, with women's access limited due to gendered differences in the division of labour.

ARC Facility	Additional benefits for poor families for each dollar spent range from 1.28-1.9 compared to baseline	Increased potential for basis-risk, causing incorrect insurance payouts	Benefits greater if only extreme events are covered. Prices must be cheap. Indices must be highly accurate.	Drought insurance stabilizes women's food consumption and health.
EGSP	Cost-benefit ratios of 2.3 for 0.7 tonne silos; 3.25 for 1.8 tonne silos. Smaller silos may not be cost effective.	High initial investment costs.	Revolving funding to finance labour and material costs. Community activities to drive uptake.	Positive impacts on women's employment and social status.
ALVs	In Nigeria, cost-benefit ratios range from 2.07-4-50 depending on species	Poor infrastructure limits market access. Lack of government involvement. Negative consumer perceptions and lack of exposure to information on ALVs.	Internal factors: farmer organization, access to cities, farmer education level and ALV experience. External factors: Health awareness among consumers, linkages with NGOs and supermarkets.	ALVs have had a positive impact on women's incomes, but increased commercialization could undermine women's role in ALV production.
NICADAPTA	Economic rate of return of 28%, Net present value of USD 127.3 million	Low institutional capacity Lack of genetic material.	Spread of technologies and agro-climatic information. Policy dialogue and private investments. Strengthening administrative capacity of MEFCCA.	Project focused on helping women and other vulnerable populations. Helps women develop rural businesses.

4. Conclusions

Ongoing and past examples of CSA interventions demonstrate that CSA projects and programmes can be designed to be effective, generating positive economic returns and benefits relating to the three CSA objectives (productivity, resilience, mitigation). These projects and programmes can also generate other co-benefits such as employment generation, health and nutritional benefits, and infrastructure development. Addressing gender and social inequalities do not appear to be amongst the primary objectives of selected cases, although several cases address these issues and provide valuable lessons. However, if CSA is to transform the agricultural sector in the face of climate change, there is an urgent need for greater attention to gender issues (Vermeulen 2015), and for making this an integral part of project design.

More precise calculations related to contributions to CSA objectives are needed, particularly for resilience and mitigation. The quantification of CSA benefits for these two pillars is less than optimal in most cases, compared to productivity. There is a need for more rigorous work around metrics for measuring resilience, which will allow quantification of these benefits. In the case of mitigation, the range of greenhouse gas (GHG) calculators available can aid precise calculations and there is a need to use such tools in ongoing and planned projects, while also conducting ex-post analysis.

The lack of rigorous evaluation work on CSA interventions has to be rectified, and there is a strong need for work that evaluates interventions based on counterfactuals, controls and baselines. Gaps in data availability, quality, and comparability, limit analysis, particularly in relation to economic costs-benefits, resilience, and mitigation. These gaps must be addressed to support ongoing efforts to scale up CSA. While conducting cost-benefit analysis on these interventions, it is essential to factor in the valuation of CSA benefits such as increased resilience and/or removal of greenhouse gas emissions.

In spite of data constraints, it is evident that several cases have positive cost-benefit ratios, and offer benefits pertaining to multiple CSA objectives. However, adoption is limited by a range of factors including high upfront costs, absence of technical knowledge, poor stakeholder engagement, and low institutional capacities. If CSA interventions are to be scaled up, investment is essential to address these barriers. Economic incentives, training and capacity enhancement efforts, stakeholder engagement activities etc. can help overcome some of these barriers.

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Appendix I: CSA Case Studies

Quantitative outcome metrics are presented where available and qualitative information is included to demonstrate the context and conditions in which interventions have taken place.

1. **Crops**

Laser-Assisted Precision Land Levelling (LLL) in India

The Indo-Gangetic Plain (IGP) contains some of the richest agricultural land in the Indian Subcontinent, and is home to approximately one billion people. Rice and wheat are key food-grains in the region, contributing 80 percent of its food production. However, the flood-irrigated land which the IGP lies upon is susceptible to undulations in the soil surface, resulting in a reduction in both land and water productivity. This is because uneven land can increase surface run-off or water logging, both of which contribute to a suboptimal distribution of water over the field. To counteract this vulnerability, farmers in the IGP have traditionally used weighted tractors or animal-drawn levelling planks to level the land. As there are limits to the accuracy of this technique, further irrigation is needed to identify high spots, which are levelled in subsequent passes. (Gill 2014 .p 1)

Laser-Assisted Precision Land Levelling (LLL) technology addresses the limitations of this practice, efficiently achieving a flat even surface. The high level of accuracy is achieved by placing a rotating laser transmitter at the edge of the field, sending information to a control box within the tractor cab to automatically raise or lower its levelling blade or drag bucket to level out undulations in the field (Gill, 2014 p. 3). CIMMYT introduced the technology to the western IGP in 2011, where it has been applied by farmers on an estimated 544,000 hectares of land. The technology has been shown to be exceptionally climate-smart, reaping considerable benefits for mitigation and adaptation, while increasing yields substantially.

Benefits in terms of productivity, resilience and mitigation

LLL contributes significantly to all three CSA objectives.

Productivity

According to a 2011 study focused on rice-wheat cropping, LLL improves food security by increasing yields within this particular rotation, leading to estimated increases of 2.85 qtl/ha for wheat and 3.22 qtl/ha for rice (Gill, 2014 p. 32). Across the 544,000 hectares of land in Haryana where LLL was applied, these yield increases resulted in an additional production of 155,000 and 175,000 MT per year for wheat and rice respectively (Gill 2014 p. 32). Furthermore, the technology promoted diversification into vegetables and other nutrient-rich foodstuffs, which plays an important role for food security by qualitatively improving diets (Gill, 2014 p. x).

Resilience

LLL improves the climate change resilience of farmers in the IGP through the reduction in irrigation requirements. Climate change has the potential to increase droughts within parts of the IGP, threatening its highly irrigation-based and ground-water dependent agricultural system. As a result, any technology which can reduce the demand for groundwater while improving, or at least maintaining, agricultural production will be key for improving the adaptive capacity of farmers. In the state of Haryana alone, LLL contributes nearly one billion m^3 of irrigation water savings per year (Gill, 2014 p. 30).

Mitigation

In terms of mitigation contributions, the technology provides multiple reductions in GHG emissions. LLL considerably lowers the need for irrigation, thus reducing the amount of fuel required for diesel-powered pumps. Across Haryana, this adds up to an estimated 163,600 MT of CO_2eq of GHG emission mitigation per year (Gill, 2014 p. 28). Additionally, fuel consumption is decreased due to the optimization of tractor time needed for land levelling, resulting in a reduction of 19,500 MT of CO_2 emissions per year (Gill, 2014 p. 28). Furthermore, the uniformly flat fields provided by LLL improve runoff control, reducing the potential for N_2O emissions and improving fertilizer use efficiency and yields (Gill, 2014 p. 29).

Other co-benefits

LLL has been described as a “precursor technology”, enhancing other climate-smart practices when they are applied in tandem (Gill, 2014 p. 40). For example, the level fields created through LLL make it easier to use technologies such as raised bed planting, turbo seeding, and crop diversification. Expansion of LLL technology also has the opportunity to create jobs and improve income, as each laser unit creates 300 work days per year, not to mention indirect employment through manufacturing, transport, etc. (Aryal et al. 2014 p. 736).

Economic costs and benefits

Calculations on the Internal Rate of Return (IRR) for LLL indicate that it is an extremely profitable investment, capable of paying back the initial cost within one to two years (Gill, 2014 p. 20). IRR ranges from 120% to 55%, depending on the presence of a government subsidy for the technology, the type of irrigation used, and whether the tractor will be applied year round for other on-farm purposes (Gill, 2014 p. 20). The initial cost of purchasing the LLL equipment and tractor are considerable hurdles to overcome, and although no farmers reported a need for repairs, the need for fuel and drivers provide persistent costs over the approximate ten year lifespan of the equipment. However, a study comparing LLL to traditional land levelling demonstrated that system profitability increased USD 113 per hectare in the first year, and USD 175 in the second year when applying the technology (Jat et al. 2009 p. 112). Furthermore, revenues derived from LLL service provisions to other farmers reap an additional USD 138/hectare/year (Gill, 2014 p. 20).

Barriers to adoption

Due to the high upfront cost of purchasing the technology, most LLL owners are large farmers (Gill, 2014 p. xi). Although a healthy and competitive market has developed for hiring out LLL services to small scale farmers, marginal farmers (i.e. cultivating less than 1 hectare of land) may be excluded from the clientele. This explanation is both technical and economic: the smallest plot that can be levelled is between 0.1-0.2 hectares, with larger plots providing greater economies of scale (Gill, 2014 p. 35).

As a result of gender norms, female headed households (FHH) in Haryana have limited access to information about new technologies (Aryal et al. 2015 p. 736). Removing these constraints may increase uptake of LLL and other climate-smart technologies (Aryal et al. 2015 p. 736).

Key success factors

A key factor for driving the adoption of LLL is ensuring its commercial profitability (Gill, 2014 p. 19). Private benefit is extremely important as it will incentivize adoption of the technology (Gill, 2014 p. 3). As mentioned above, LLL has been shown to increase resource productivity, thus increasing profitability; yield increases are accompanied by a reduction in resource consumption, making the technology very economically attractive to farmers (Gill, 2014 p. 13).

Government subsidies have played an important role in the success of the initial uptake in Haryana, by reducing some of the initial costs. However, due to the development of a high demand for LLL services and the resulting lucrative returns on investment, they could currently be phased out without lowering uptake, allowing investment into other CSA practices (Gill, 2014 p. 42).

Social organization may help overcome the diseconomies of scale hampering the adoption of LLL among marginal farmers. Some groups of marginal farmers have removed the boundaries between their land and successfully hired out LLL services, re-establishing the boundaries after the land has been levelled (Gill, 2014 p. xi).

Gender and social equality

There is some evidence that LLL provides labour market opportunities for female labour, despite the fact that few FHH with agricultural land farm it themselves (Gill, 2014 p. 37). As mentioned previously, LLL has been shown to promote crop diversification into vegetables. The labour-intensiveness of these crops, combined with the lower wage rate of women, provides incentives for hiring female labour (Gill, 2014 p. 38). Furthermore, a 2014 survey indicates that women farmers have been able to hire out LLL machinery, but again cultural norms provide a barrier, as it is not customary for FHH to approach male LLL owners directly (Gill, 2014 p. 37).

Alternative Wetting and Drying (AWD) in Vietnam and Bangladesh

Rice is one of the most widely cultivated food crops globally and is eaten by more than half of the world's population every day (IRRI, 2015). The vast majority of production and consumption is accounted for by Asia (FAO 2015b). Over the last two decades, rice farmers throughout the region have adopted a range of practices to reduce their input use whilst maintaining, or even increasing yields and profitability. Alternative Wetting and Drying (AWD) is one such management practise in paddy rice production which shows promise of multiple benefits. AWD can be considered an example of climate-smart agriculture (CSA), in that the practise has the potential to enhance yields, improve resilience to climatic hazards and reduce greenhouse gas (GHG) emissions.

Evidence of the benefits resulting from this practise of periodic drying and re-flooding of the field has been documented for Bangladesh and Vietnam; the fourth and fifth largest rice producers respectively (FAO 2015b). In both countries, paddy rice production is both a major constituent of agricultural land use and GHG emissions. In Vietnam, 7.9 million ha are in production. This contributes over a quarter (26.1%) of national emissions and represents 58% of the agriculture sector's emissions (FAO 2015b; Vietnam's National Communication to the UNFCCC, 2014). For Bangladesh, around 11 million ha are in production, which represents 8% of national emissions and 18% of the country's agricultural sector emissions (Bangladesh's National Communication to the UNFCCC, 2012).

Benefits in terms of productivity, resilience and mitigation

Productivity

Benefits of AWD in terms of reduced water use and reduced GHG emissions can be realised without undermining yields. In fact yields may increase when practicing AWD as a result of more effective tilling and stronger root growth of rice plants. Specific to cases documented for implementation of AWD in Bangladesh, yield increases were found to be between 5% and 13% (0.3 to 0.7 tonnes/ha) (Basak, Forthcoming a p. 7). The equivalent range in values for the impact of AWD adoption in Vietnam is wider; between 0% and 12% (0 to 0.7 tonnes/ha) (ibid).

Resilience

By reducing the number of irrigation events required, AWD can reduce water use, thus farmers are better able to cope with water scarcity.

Mitigation

The practice of allowing the water level to drop below the soil surface at one or multiple points during cultivation has been used for several decades as a water-saving technique (Basak, Forthcoming a p. 6). However, when correct phasing of the drying/flooding events is practiced in combination with additional measures, optimal levels of GHG mitigation and additional co-benefits can be achieved (Richards & Sander, 2014 p. 1).

Studies of conventional puddled rice cultivation in Bangladesh indicate average emissions per hectare of 3.3 tonnes of CO2e, whereas cultivation using AWD yields lower levels; 2.5 tonnes of CO2e per hectare (~800kg CO2e less, or around a 25% reduction) (Basak, Forthcoming a p. 8). Fuel savings resulting from lower levels of water pumping under AWD further decrease emissions by 32 kg to 106 kg of CO2e per hectare (ibid.). Estimates of emission reductions resultant from fuel savings are not found within literature relating to AWD cases in Vietnam. However, emission reductions resultant from lower methane emissions have been estimated, albeit with considerable ranges, from as little as 1.8 to as much as 4 tonnes of CO_2e per hectare (approximately a 40-60% reduction) (ibid.). AWD can also reduce methane (CH4) emissions, particularly when implemented in combination with improved management of nitrogen and organic inputs.

Other co-benefits

For Bangladesh, water savings were found to be in the order of 22% to 26%, representing between 2,580 and 3,590 m3 of water saved per hectare (Basak, Forthcoming a p. 8). For Vietnam, water savings associated with AWD adoption were documented in the order of 40% to 50% (ibid).

Economic costs and benefits

Paddy rice cultivation in both Bangladesh and Vietnam generally makes use of pumped irrigation. And so a key element of cost savings found through the adoption of AWD is through lower irrigation costs (both in terms of reduced water fees and fuel for water pumping) (Basak, Forthcoming a p. 6). Several estimates of this reduction in costs are found within the literature. The majority of cost savings in cases from Bangladesh were from reduced water costs, though in some cases this was offset by an increase in pre-harvest labour and fertilizer costs. Consequently, implementation of AWD was found to marginally increase or decrease production costs in Bangladesh by a few percent (ibid.). For cases documenting adoption of AWD in Vietnam, the cost savings are clearer. One study found irrigation costs to be 30% lower under AWD production, compared to conventional puddled rice (Quicho, 2013). Furthermore, the same study found that the total costs of production under AWD (USD 538 per hectare) were 20% lower than the farmers' conventional practice (USD 676 per hectare) (ibid.).

The increase in yields associated with using AWD, coupled with general reduction in production costs, translates into an increase in overall profit. The profit (i.e., gross returns minus costs of production) ranges between USD 575 and USD 1202 per hectare for conventional puddled rice grown in Bangladesh, whereas it ranges from between USD 704 and USD 1301 for rice grown using AWD (Basak, Forthcoming a p. 7). This represents an increase in profit of between 8% and 39% (between USD 98 and USD 235 per hectare). For cases in Vietnam, profits under conventional practice are between USD 873 and USD 981 per hectare, and between USD 1101 and USD 1341 for cases practising AWD (Quicho, 2013; Basak, Forthcoming a p. 7). This constitutes an increase in profit of 17% to 41% (or between USD 170 and USD 391 per hectare).

Barriers to adoption

The main barrier to adoption of AWD practices are prohibitive transaction costs (Basak, Forthcoming a p. 9). For example, even though the technology may have been demonstrated as effective in one location, farmers must then evaluate their own local situation, seek out additional inputs if required and front the initial costs which may arise in the implementation/learning phase. All of these take time and resources and may contribution to farmers' aversion to adoption. In some situations, water costs may be relatively high, and so AWD would be particularly cost effective, rapidly yielding net savings. Yet, even if cost is not a barrier, knowledge of how to appropriately operate the system may present an obstacle. In particular, farmers need to be aware of when the water levels are to be maintained (during flowering and grain filling stage) and when it is best to drain, and to what specific depth (Richards and Sander, 2014).

Furthermore, there may also be socio-economic, cultural, and political reasons why rice growers are hesitant to adopt new irrigation technologies, especially where evidence of success has not been effectively communicated at the local scale (Burnham et al. 2014; Alcon et al. 2014). For example, AWD is largely just a modification of existing, often widely practised drainage/irrigation practises. Yet, prevailing cultivation practices may be ingrained, having been cultivated this way for generations (Richards and Sander, 2014 p. 1).

A key risk to securing the benefits of AWD is the incorrect timing of irrigation/drainage, as this can lead to large yield declines. As such AWD is generally not recommended for rainfed systems where farmers lack control over irrigation (Richards & Sander, 2014 p. 2).

Key success factors

Factors which contribute to adoption include the level of outreach and extension support, scale of involvement with farmers' groups and advisors, size of barriers to adoption (namely, transaction costs, information provision) and finally, and the size of the financial incentive to adopt (Basak, Forthcoming a p. 9; Castillo, 2012). Accordingly, regions where farmers face higher irrigation costs would likely have a greater financial incentive to adopt. This incentive to adopt AWD could be enhanced and aligned with water saving schemes by engaging with government agencies or irrigation service companies to institute water payment schemes (Basak, Forthcoming a p. 9). Furthermore, those regions exhibiting the greatest yield gap could be used as a criteria for targeting diffusion efforts, as yield increases resulting from AWD may be sufficient in incentivising adoption, even in the case where irrigation water is unmetered (ibid.).

Gender and social inequality

Few studies have assessed gender specific impacts of AWD adoption, and fewer still focus upon the role of women or marginalised groups in the use of this particular practise. On average, women provide nearly half of the labour input in Asia's rice producing areas (Mohanty and Bhandari, 2014 p. 42). However, the share is much lower in Bangladesh where women's involvement in rice farming is minimal and limited to postharvest activities mainly because of their religious and cultural practices (ibid). In Southeast Asian countries, the labour input of women into rice production has been declining due to outmigration of rural women and mechanization (ibid). This is indicative of a more general trend across Asia, where women are going from farm labourers to farm managers and owners because of the outmigration of male farmers to urban areas in search of better economic opportunities. However, the share of agricultural land owned by women is still low across the region particularly in Bangladesh and Vietnam (5 and 10% respectively) (ibid). These recent trends are expected to continue and will necessitate policies and programs that will strengthen women's access and control of resources and services (WRI, 2014 p. 4).

Coffee-Banana Intercropping (CBI) in East Africa

In East Africa, coffee production is likely to be severely affected by climate change. It is estimated that the area suitable for coffee production will decline by about 50% relative to the period 1971-2000 (Ramirez-Villegas & Thornton, 2015). The most negative impacts are likely to be on Arabica coffee systems. This is of concern because coffee is one of the most valued export crops for the tropics (Craparo, 2015 p. 1). Coffee is highly sensitive to even slight changes in temperature, having negative impacts on yield and quality Providing shade is a promising method of climate adaptation, but growing trees capable of blocking the heat can take up to 10 years. To speed up the resilience of coffee farmers, Coffee-Banana Intercropping (CBI) is capable of achieving full canopy cover within 6-12 months. Coffee and banana can be planted at the same time, or either crop can be added to an existing plantation, requiring only slight pruning and thinning to make sufficient room for both crops. CBI is already widely practiced across the East African highlands, and is seen in coffee-systems in Asia, Latin America and West Africa as well.

Benefits in terms of productivity, resilience and mitigation

CBI contributes to all three CSA objectives.

Productivity

CBI does not cause a significant reduction in coffee yields compared to monocrops (van Asten et al. 2011 p. 328). While banana yields per unit area can be reduced by up to 50% when intercropping, the added diversification has other income and food security benefits. Adding bananas to coffee systems can alleviate household under-nutrition, especially for children, by providing a rich source of vitamins A, B and D. Household income sources become more diverse as well, reducing risk of income loss if one of the two crops fails. Coffee grown under shaded conditions has been shown to produce better quality beans as well (Vaast et al. 2006), fetching a higher market price and improving farmer incomes.

Resilience

Not only does CBI improve climate change resilience through shade canopy, the system becomes more resilient to other extreme weather events, such as drought and hailstones. Bananas can remain highly hydrated under drought, meaning that the coffee plants will have to compete less for water compared to intercropping with other shade trees.

Mitigation

CBI also contributes to GHG mitigation through increased efficiency in the use of resources for production. Compared to monocultures, the average combined carbon stocks in coffee and shade trees increased from 10.5 Mg ha^{-1} to 30.2 Mg ha^{-1} in commercial polycultures (van Rikxoort et al. 2014 p. 891). The overall increase in productivity garnered through CBI means that the carbon footprint of the system is reduced, as the emissions caused by the inputs used cover a larger agricultural produce.

Other co-benefits

CBI provides *in situ* mulch from the bananas, reducing the need for expensive and labour intensive mulch transfer from other sites. *In situ* mulch from banana suppresses weeds and helps recycle organic matter and nutrients.

Economic costs and benefits

CBI provides the greatest benefits for newly established coffee farms, due to the 3-5 year juvenile period of coffee crops. The practise greatly improves the initial returns on investment, as bananas are ready for harvesting within 1-1.5 years after establishment. In addition, yield value per unit area of land is increased greatly compared to monocrop systems, with an average land equivalent ratio of over 1.5. For both Arabica and Robusta systems, CBI generates 50% more revenue than when either crop is grown alone, as shown in Figure 1.

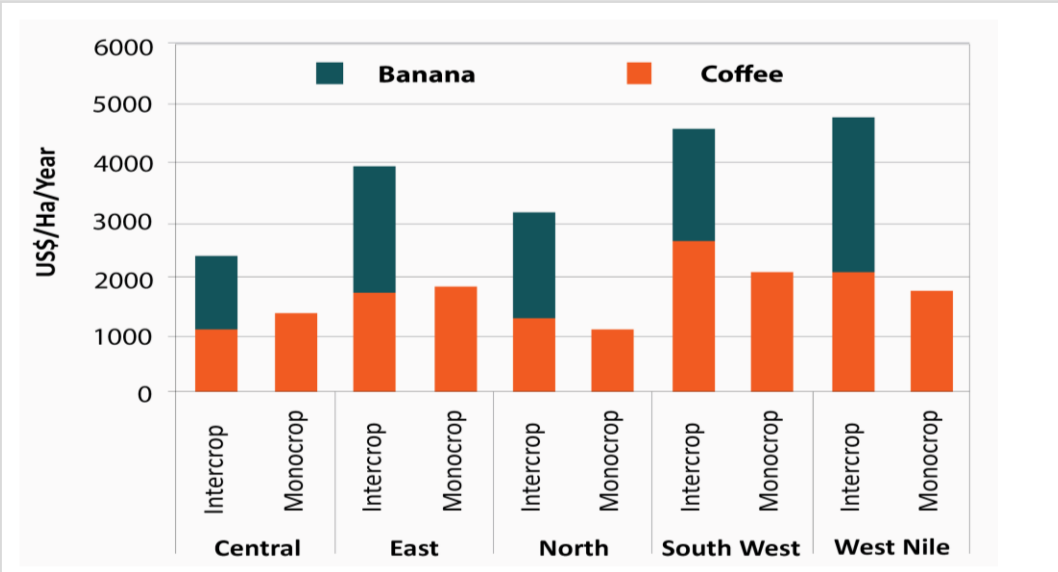


Figure 1 Example of coffee-banana intercropping revenues as compared to coffee mono-cropping plots from large on-farm studies (n=357) in Uganda. Central and North are Robusta coffee growing regions; East, (Source: Ochola et al. Forthcoming)

Barriers to adoption

Establishing a CBI system is costly, due to upfront capital and labour costs. Despite the long-term rewards mentioned previously, these initial costs can be prohibitive for subsistence farmers, who like to obtain immediate returns on their investments.

Key factors to success

The benefits of CBI can be optimized further through several additional practices, such as improved soil management, as well as optimal plant arrangements and densities (van Asten et al. 2011 p. 332). In order to encourage farmers to engage in CBI, major production constraints must be identified, and addressed through subsequent site-specific recommendations (van Asten et al. 2011 p. 333). Further science- and evidence-driven guidelines are required, as well as formal recommendations on CBI practices. Special training is necessary as well, to make sure farmers achieve the right balance between the two crops, as careful management of soil and leaf canopies is required. In order to maintain yields and ensure long-term sustainable productivity, correct management of soil nutrient stocks is imperative, as the competition between the two crops can be heavily taxing.

Gender and social inequality

CBI does not have a specific gender component. However, women farmers contribute greatly in terms of labour to coffee production, but there are imbalances in terms of plantation ownership.

GreenSeeker technology for better nitrogen management in India and México

Within the high Northwest Indo-Gangetic Plains of India, intensive tillage and overly-generalised fertilizer recommendations have limited the potential of the region's high-yielding wheat production systems (Sapkota et al. 2014 p. 233). These sub-optimal practices have resulted in lowered nutrient use efficiency, lower profits, as well as higher production costs and significant environmental impacts (Sapkota et al. 2014 p. 233). Although no-tillage practices have been scaled-up in the region, farmers have trouble accessing proper information on optimal nutrient management practices that match their specific contexts (ibid).

To support farmer decision making, site-specific nutrient management tools have been developed, such as the GreenSeeker handheld sensor, which can be quickly used to assess crop health. Farmers simply position GreenSeeker's sensor over a plant and pull the trigger, outputting calculations of the appropriate fertilizer dosages (CIMMYT 2012). With proper knowledge of crop vigour, farmers can make more informed decisions on fertilizer use, benefitting the environment and farmers input costs. The technology has been applied in both India and Mexico.

Benefits in terms of productivity, resilience and mitigation

Precision nutrient management technology, such as GreenSeeker, provides gains in mitigation and productivity.

Productivity

Proper timing and placement of nitrogen fertilizer can improve uptake efficiency, yield, emissions and profitability. Generally, application is most effective when applied during the initial crop development phase – i.e. at planting time, or soon after (Flynn, 2009). Compared to farmers utilizing state recommended nutrient management or farmers own fertilizer practices, farmers using GreenSeeker in India saw 10% increases in yields (0.5 tonnes/ha). These yield increase and nutrient-use efficiency gains translated into an increased net income of USD 187.50/ha (Basak, Forthcoming b p. 9).

Resilience

Precision nutrient management does not offer any explicit resilience gains.

Mitigation

Through improvements in the preciseness of nutrient dosage, a field study in Mexico found that the use of the GreenSeeker optical unit reduced fertilizer use by 68 kg/ha, reducing GHG emissions associated with the fertilizer use reduction by 190 kg CO_2e/ha (Basak, Forthcoming b p. 9). In India, farmers using GreenSeeker reduced GHG emissions by 47% (0.9 tonnes CO_2/ha) (Basak, Forthcoming b p. 9)

Other co-benefits

All major benefits fall under CSA objectives.

Economic costs and benefits

The study by Sapkota et al. (2014) on precision nutrient management techniques used in wheat cultivation aided by the GreenSeeker technology in a field trial in North West India made estimates of the impact upon total implementation costs, gross and net return. Total input costs were USD 69 per hectare lower compared to conventional techniques, which when combined with higher yields under the precision system, contributed to an increase in net income of USD115 per hectare (~30% increase) (Sapkota et al. 2014). A comparable field study in Mexico found that the GreenSeeker optical unit reduced fertilizer use by 68 kg/ha, saving USD83/ha (7% of total production costs) (Basak, Forthcoming b p. 9). GreenSeeker units cost approximately USD550, meaning that the costs can be reimbursed in under 7 years (Basak, Forthcoming b p. 9).

Barriers to adoption

The main barrier restricting wider uptake of precision nutrient management technologies such as the GreenSeeker unit are the up-front costs (currently USD 550 excluding any subsidy support or ongoing maintenance costs) (Basak, Forthcoming b p. 9). The unit is simple to use, so training new users in carrying out surveys and interpreting results is not a significant investment (ibid.).

Key success factors

Realisation of the potential benefits of GreenSeeker-type technologies will primarily involve addressing low penetration rates. Tax relief on purchase of the unit has been used by the Mexican government as a means of promoting the technology (ibid.). Other options exist for lowering costs, including subsidy programs, cost-sharing schemes between neighbouring farmers or farmers' cooperatives, or a pay-per-use system.

Gender and social inequality

No explicit gender focus is found within this project

2. Fisheries

Aquaculture in the Mekong River Delta

The mighty Mekong River is a hub of aquaculture activity. The river is a source of 18% of the global freshwater catch and supports the livelihoods of some 60 million people within its lower basin (Baran & Borin, 2012). Shrimp and catfish are the key species in Vietnamese culture fisheries and dominate both production volume and value. These species contribute directly or indirectly to the majority of poorer Vietnamese households (Baran & Borin, 2012). Moreover, the past decade has seen culture of these species develop into a highly commercialised industry which now represents over 7% of GDP (GSO, 2013).

However, despite these prospects, individual farmers will continue to face stiff competition and tight margins, and any unforeseen costs could jeopardise these operations. The impacts of climate change in the region present numerous hazards and are of particular concern to culture fisheries, the majority of which are exposed on the banks of rivers or the coast. Changing rainfall patterns are expected to lead to greater incidence of flooding and drought periods, as well as the potential for a decrease in freshwater availability (Norman, 2015 p. 4).

The impacts of the climatic hazards are seen across several components of the aquaculture system and accordingly several separate measures are necessary in response. Reinforcement of dykes can assist in maintaining water levels during drought and also protect culture ponds against flooding. Changing species and managing stocking rates can alleviate negative impacts of temperature pressure fisheries. Likewise, more tolerant strains of cultured species can combat saltwater intrusion, whilst also enabling farmers to avoid relocation and minimise changes to current management practices. Relocation of production to higher, cooler elevations is a drastic but practical response to increased temperature stress. Together these measures can address all the aspects of CSA.

Benefits in terms of productivity, resilience and mitigation

Adaptation in aquaculture contributes to all three CSA objectives.

Productivity

The precise combined impact of climate change upon aquaculture operations is not shown in the literature as models which link climate change and aquaculture production and yields are yet to have been conducted (Kam et al. 2012 p. 20). However, none of the adaptation measures described present trade-offs between productivity and resilience. Catfish aquaculture in the lower Mekong is currently among the most productive systems found anywhere, yielding 200-400 kg/ha, meaning 15 to 25 fish/m3 at the time of harvest (De Silva & Phuong, 2011). Maintaining such levels will require that climatic hazards are countered.

Resilience

All aforementioned adaptation measures foster resilience against more variable and adverse climatic conditions.

Mitigation

The main sources of GHG emissions from aquaculture products are from production and electricity for pumping water (Hall et al. 2011). Adaptation measures relevant to the sector can also act upon these components of mitigation as well. For example, improved water resource management, pond reinforcement and coordination with hydropower development can all limit the requirement for water pumping and therefore GHG emissions.

Life-cycle assessments of the Pangasius species of catfish in the region have shown a higher environmental footprint compared with aquaculture operations in other regions. Regarding GHGs specifically, operations in the Mekong resulted in nearly nine tonnes of CO_2eq per tonne of product which is ten times the carbon footprint of integrated agriculture-aquaculture systems (Bosam et al, 2011; Kluts et al, 2010). However, it is unlikely that integrated agriculture-aquaculture systems could support the same level of output as intensive technique. Reductions in the GHG intensity could therefore be found in measures which lower emissions from feed inputs. Integrated multi-trophic aquaculture is one approach to achieving this outcome. In this set-up, species for different levels of the food chain are cultured together so that the by-products, including waste, from one aquatic species become inputs for another (Barrington et al. 2011 p. 10). Depending on system design and set up, energy input sand GHG emissions can be reduced, and furthermore, a diversified selection of species increases the resilience of the operation to both changes in environmental and market conditions.

Other co-benefits

Planned adaptation measures targeting salinity intrusion and flooding, such as sea defences, better land use planning and coastal forest protection, will also have ancillary benefits to other sectors, particularly other agricultural operations.

Economic costs and benefits

Kam et al (2012) estimated the costs and benefits of striped catfish and shrimp culture aquaculture operations in the Mekong Delta in the near and longer term, under both changing and stationary climatic conditions. In the near term, the vulnerability to profitability for both coastal and particularly inland catfish operations is highlighted, not least due to the fact that farmers operate such tight margins. Their study assumed that farmers would field the costs of adjusting their operations to cope with a changing climate, however, the largest constituent of variable costs were feed, seed and bio-chemicals, which are less climate-sensitive. The study also assessed what level of planned adaptation would be required to achieve the same level net income as in a case where farmers adapted autonomously. Here planned adaptation measures refer to infrastructure project which prevent flooding and salinity intrusion. For striped catfish and shrimp systems, about USD 172 million will be spent for dike upgrading and USD 18 million for increased costs in electricity and fuel due to climate change, totalling USD 191 million over the 10-year period 2010–2020.

Barriers to adoption

In a recent study, farmer’s education level, age and experience, the dependency on income from aquaculture and whether they own the land were shown to be positively correlated with awareness of and concern about climate change impacts. Accordingly, a lack of these attributes may hold back the adoption of viable adaptation practises.

Key factors to success

The Ministry of Agriculture and Rural Development has developed the ‘Overall Development Plan for Vietnam’s Fishery Sector until 2020 With a Vision to 2030’ which anticipates a near doubling of production output from the fishery sector by 2030. Achieving this vision will require that pervasive effects of climate change are managed through the implementation of the adaptation measures discussion above. Coordination efforts with neighbouring countries will also be necessary with whom water resources are shared. Additional constrains on successful realisation of this goal are stricter food safety standards and increasing pressures on producers from retailers and buyers for more healthy and sustainable production.

Gender and social equality

These aquaculture adaptation measures have no specific gender components.

Fish ring microhabitats in Bangladesh's rice fields

In Bangladesh, the monsoon season leads to extremely variable weather conditions. Due to changes in water flows during flooding, fish are shuttled from rivers and canals into nearby rice fields. However, the fish may become trapped in depressions when the water recedes, and die due to drought, high temperatures or low oxygen levels in the remaining shallow waters (Hossain et al. 2015 p. 2). Fish ring microhabitats can be constructed to take advantage of the fact that the annual monsoons coincide with the spawning period of many of the fish species which enter the floodplains (Hossain et al. 2015 p. 2). These fish rings, developed by WorldFish, consist of three small cement rings (approximately 76 cm across and 1 m deep), which are buried in the rice field prior to flooding. When flooding occurs during the monsoon period, the migrating fish naturally gather in the deep, cool water housed within the concrete walls, acting as a microhabitat for fish to thrive and breed. After the monsoon season, the remaining fish can be consumed or transported into household ponds, providing additional sources of food and income.

Benefits in terms of productivity, resilience and mitigation

Fish rings contribute to increased incomes and food security, providing resilience to harsh flooding events.

Productivity

The fish gathered in the fish ring can either be directly consumed by farmers, or sold for additional income. On average, fish rings bring 0.5-1.5 kg of fish fit for consumption per household throughout the year (Hossain et al. 2015 p. 4). Additionally, the fish can be used to fill out the stocks of farmers' home ponds for no cost.

Resilience

Fish rings can help farmers increase resilience towards flooding, since even if flooding damages their rice crops, they are able to rely on the fish catch as an alternative food source.

Mitigation

Fish rings do not offer any direct contributions to mitigation.

Other co-benefits

Almost 90% of all fish caught in the fish rings were small, nutritious fish species, improving household nutrition. Rice fields with fish rings have a greater diversity of indigenous fish species, with a 92% survival rate of fish, compared to a 0% survival rate in fields without fish rings (Hossain et al. 2015 p. 8).

Economic costs and benefits

Studies indicate that there is an increase in the number of fish within rice fields which contain fish rings, with no negative impact on rice yield. These fish bring in extra income of about 1.5-2 kg per fisher (Hossain et al. 2015 p. 8). The cost of the material for constructing the three cement rings is approximately USD 11, making them quite low investment for valuable food security and livelihood benefits.

Barriers to adoption

Initial investment costs, though small, may be a disincentive for some farmers. As fish rings depend on water flows and rice field elevation, some farms may be more suitable for fish rings than other. (Hossain et al. 2015 p. 5).

Key success factors

Fish rings must be placed at proper locations, and marked with bamboo poles so they do not become a hazard. Farmers should observe where the fish enter the rice field from during the flooding months, especially from nearby rivers and canals which house many fish (Hossain et al. 2015 p. 5). After flooding, farmers must observe and identify low-lying areas in the rice fields where water will likely flow to, as these make ideal sites for fish rings. As rice fields are typically shared by landowners, sharecroppers and farmers, community-based management schemes can help prevent outside poaching, and ensure a thriving microhabitat (Hossain et al. 2015 p. 6).

Gender and social inequality

Fish rings microhabitats do not have any inherent gender component.

3. Landscapes

Farmer-managed natural regeneration (FMNR) in Niger

Niger is one of the poorest countries in the world, and has been challenged by crop failures, extreme climate events and food insecurity for decades. Population increases during the 1960s-70s have been linked to degradation of Niger's parklands, as demand for wood products increased and led to rapid deforestation (Pye-Smith 2013 p. 8). In combination with frequent and severe droughts, the degraded farmland was unable to provide sufficient food to feed the country's growing population. Despite government plans to plant 60 million trees, fewer than 20% of them survived (Pye-Smith 2013 p. 9). But underneath the degraded lands, extensive systems of living roots survived and thrived. Since the early 1980s, the Farmer-Managed Natural Regeneration in Niger

(FMNR) approach has capitalized on these hard roots to improve the resilience and livelihoods of farmers in Niger, while providing increases in food security and enhancing carbon sequestration.

FMNR involves identifying and protecting tree and shrub wildlings found on farmland. The practice depends on living tree stumps and root systems, which grow more quickly than saplings from seeds. This woody matter is normally grazed by livestock, burned off, or harvested for timber, and does not grow to full tree stature. But by protecting these stumps and shrubs, and pruning away the weaker stems, they can grow into full-sized trees. These trees can have useful traits, such as *Faidherbia albida*, which sprout leaves during the dry season, protecting the crops below, and drop them again during the rainy season, making the soil fertile (Pye-Smith 2013 p. 11). As a result, crop yields on the regenerated fields are higher.

Benefits in terms of productivity, resilience and mitigation

FMNR contributes to all three CSA objectives.

Productivity

FMNR contributes both directly and indirectly to increase household food security. FMNR fields exhibit enhanced crop yields, improving cereal yields by an average of 100kg/ha (Reij et al. 2009 p. 19). At the estimated scale of 1.5 ha rehabilitated per household of 8 persons, FMNR contributes approximately 500,000 tonnes of cereals, providing food for 2.5 million people (Reij et al. 2009 p. 19). In addition, the presence of tree crop products within FMNR provides more fodder and crop residues. This allows farmers to improve their productivity by intensifying and improving their livestock production. In turn, the increased supply of manure can be used to improve soil fertility (Reij et al. 2009 p. 19). Tree products can also be sold for their medicinal qualities or as construction material, providing enhanced incomes for farmers.

Resilience

For drought-prone areas such as Niger, resilience to climatic extremes is crucial. The increased tree canopy from FMNR protects crops from harsh Sahelian winds. The greater yields achieved through the less degraded, better quality soils permits the surplus in good years to balance deficits in years with poorer yields.

Mitigation

Although a systematic investigation of the mitigation impact of FMNR has not yet been conducted, carbon sequestration has been increased and deforestation has been reduced. Over 5 million hectares of land have been covered with approximately 4.5

tonnes of above ground biomass per hectare, in addition to over 200 million trees (Reij et al. 2009 p. 2).

Other co-benefits

The program strengthened social capital amongst farmers, through participation in the community groups. Human capital was boosted as well via farmer-to-farmer knowledge sharing (Tougiani et al. 2008 p. 381). Some regenerated trees provided additional benefits such as medicinal leaves, which could also provide income increases. The multitude of farmer benefits derived from FMNR have also reduced incentives to migrate away from farms (Cooper et al. 2013 p. 76-77).

Economic costs and benefits

FMNR is a very low cost practice. Table 5 gives an indication of the costs and impacts of the project since the mid 1980s. For only USD 20/ha, crop yields are increased about 100 kg/ha (Reij et al. 2009 p. 2).

A 2006 study calculated the IRR of FMNR, by assessing the value of firewood to be produced over a 20 year period, in addition to 5% increases in cereal yields over an initial 5 year period, bringing a healthy IRR of 31%, (Reij et al. 2009 p. 39). Furthermore, this parsimonious assessment does not take into account the counterfactual alternative to FMNR, i.e. the absolutely devastating agro-environmental conditions of the 1980s, which had huge costs in terms of human well-being (Reij et al. 2009 p. 3). Taking into account all factors, including enhanced soil fertility and increased food, wood and fodder supply, FNMR brings an estimated benefit of USD 56/ha per year (Cooper et al. 2013 p. 77).

Table 5 Impacts from farmer-managed natural regeneration in Niger (Adapted from Reij et al. 2009 p. 2)

	Impacts of Farmer-managed natural regeneration in Niger
Area covered	5,000,000 ha
Average cost/ha	USD 20 (to protect trees and shrubs)
Crop yield change	100 kg/ha
Additional cereal production/year	500,000 tonnes
Households covered	1.25 million
Increase in number of trees	200+ million
Average above ground biomass	4.5 tonnes/ha

Barriers to adoption

One of the greatest barriers to implementing FMNR is overcoming the lack of knowledge. Gaining an understanding of how to propagate trees was crucial for successful implemental of the project. Furthermore, government policy hindered the FMNR during the 1980s by promoting the removal of tree stumps to allow for oxen-driven ploughing (Haglund et al. 2011).

Key factors to success

Luckily, FMNR is a fairly simple practice, meaning that overcoming the knowledge barrier is a realistic and achievable target. Smallholder farmers have been able to overcome this barrier largely through farmer-to-farmer knowledge sharing, as well as FMNR community groups, through the assistance of NGOs and extension services (Tougiani et al. 2008 p. 381). However, the pre-existence of sufficient social capital is necessary to ensure the spread of word of mouth information. Community programs such as the Desert Community Initiative played an important role, and were successful by being inclusive to all stakeholders, building upon local knowledge, and creating a cooperative environment which drove farmer innovation (Tougiani et al. 2008 p. 388).

Gender and social inequality

Women may have benefitted the most from FMNR, from the improved supply of water and tree products brought on through the project (Reij 2009 p. 20). FMNR favours women, as it requires year-round tending, where many men migrate during the dry season. Women farmer incomes have also been increased from selling the leaves of various trees and fruits. The stronger economic position of women grants them a better capacity to improve the diets of their families, and make further investments that improve productivity, such as purchasing goats and sheep (Reij, 2009 p. 20).

Loess Plateau watershed rehabilitation project

The Loess Plateau in Northwest China is home to 50 million people, but centuries of overgrazing, overpopulation and overuse led to some of the highest erosion rates in the world, and severe poverty. Two consecutive projects (1993-2000 and 2000-2005) launched by the Government of China with funding from the World Bank brought more sustainable agricultural production into the area and helped restore the heavily degraded Loess Plateau. Efforts to restore the Loess Plateau included campaigns to terrace slopes, plant shrubs and trees in marginal sloping farmland, as well as building small dams to impede sediment runoff (World Bank 2007b p. 13).

As a result of the project, land use conversion has benefitted 2 million ha of land, while helping 2.5 million households out of poverty (World Bank 2007a).

Benefits in terms of productivity, resilience and mitigation

The rehabilitation of the Loess Plateau contributed to all three CSA pillars.

Productivity

As a result of the project, household income of participants grew from approximately USD 70 to USD 200 per person per year, through the enhancement of agricultural productivity and diversification (World Bank 2007a). Over 2.5 million people from some of China's poorest provinces were lifted out of poverty (World Bank 2007a). Food supplies were increased as well, through terracing which both increased yields and significantly reduced yield variability. Households in some areas increased their net incomes through increased off-farm employment, as a result of migration away from the farm (Cooper et al. 2013 p. 79). Due to the reduction in labour required by more efficient farming practices such as terracing, farmers were also able to improve income and food security by participating in livestock production, as well as fruit and nut tree production (World Bank 2007b p. 21).

Resilience

The project successfully reduced the sedimentation of waterways flowing from the Loess Plateau into the Yellow River by over 100 million tonnes per year (World Bank 2007a). As a result of better sediment control, the risk of flooding was reduced, in addition to a network of dams which contained water when rainfall was low (World Bank 2007a).

Mitigation

In the county of Mizhi within the Loess Plateau, farmlands converted to forest or grassland had a 58% higher soil organic matter content compared to non-converted lands, with an estimated soil organic carbon potential of .712 million tonnes carbon per year (Cooper et al. 2013 p. 79). Furthermore, the project established 109,000 ha of forest trees, contributing to carbon sequestration (World Bank 2007b p. 22). The project also includes a ban on livestock grazing, adding an additional mitigation component.

Economic costs and benefits

The project cost USD 240.2 million at completion (World Bank 2007b p. ix). Calculations of the economic/ecological benefit of the increase in soil organic matter alone have an estimated benefit of RMB 16.07 million (approximately USD 2.6 million) in Mizhi county (Shi and

Wang 2011 p. 15765). It is worth considering the counterfactual situation as well, where the degradation of the Loess Plateau, with over 60% of the area facing soil erosion and water runoff, had led to the loss of agricultural land worth an estimated USD 1.28 billion (Cooper et al. 2013 p. 78). Measurements of overall economic rates of return vary from 18% to 21% (World Bank 2007b p. xi).

Other co-benefits

More efficient crop production through terracing and agricultural diversification brought on increases in both on- and off-farm employment, increasing the employment rate from 70% to 87% during the second project period (World Bank 2007a). Roads constructed for the project also improved access to off-farm employment, education, and health services (World Bank 2007a p. xi).

Barriers to adoption

One key barrier to overcome is ensuring the re-employment of surplus rural labour provided through more efficient agricultural production (Shi and Wang 2011 p. 15769).

There is also a risk that local authorities may not continually uphold the grazing ban, and assist with maintenance of the terraces in the case of climate-related damages (World Bank 2007b p. 24). Some farmers may not be willing to lose income while waiting for their trees to mature and bear fruit (World Bank 2007b p. 24).

Key success factors

Terracing was a key contributing practice to the success of the project, as they reduced on-farm labour requirements, in addition to reducing flood risk, while transforming previously unusable land into valuable cropping areas (World Bank 2007a). However, terracing hinged on the development of infrastructure in the form of roads, to allow vehicles, labour and farmer equipment to access the previously unproductive areas (World Bank 2007a).

The project's success was driven through close partnership between development organisations and the Government, facilitated by enabling policy, technical support and active community participation (World Bank 2007a).

Gender and social inequality

Employment rates for women increased significantly as a result of the project (World Bank 2007a).

4. Livestock

East Africa Dairy Development (EADD) Project

In many households across Kenya, Rwanda and Tanzania, a large portion of household income is derived from dairy. Despite the value of dairy cows for African farming families, a lack of optimal production technology, access to inputs and business skills limits the sector from exploiting its full potential. Furthermore, climatic stresses and degraded lands cause food insecurity for both people and their livestock, necessitating a more resilient dairy production chain.

To address these challenges, Phase I of the East Africa Dairy Development (EADD) project was launched in 2008 in a partnership between Heifer International, ICRAF, ILRI, TechnoServe and African Breeding Systems, funded by the Bill and Melinda Gates Foundation. The programme specifically targeted smallholder farmers, with the goal of helping 179,000 families overcome poverty and meet their nutritional needs through enhancing the productivity and quality of milk. EADD provided better business delivery services, chilling and processing, while providing production inputs and market access through local business hubs (Wambugu et al. 2014 p. 3-4). Phase II runs from 2014-2019 and aims to help an additional 136,000 smallholder families in East Africa achieve sustainable livelihoods (Heifer International, 2014a p. 2). In areas where the dairy industry has already matured, new technologies and innovative fodder production approaches will be incorporated (Heifer International, 2014b). EADD has adopted CSA as an overarching objective in Phase II.

Benefits in terms of productivity, resilience and mitigation

EADD contributes to all three CSA objectives.

Productivity

Increasing milk productivity through intensified production brings both income gains and leads to the availability of a larger variety of dairy products, improving diets. Livestock productivity is improved through the use of high quality fodder production and stall feeding (Jönsson 2012 p. 11). Farmers are also trained in proper management of livestock health and improved livestock breeding, leading cows to produce higher volumes and quality of milk (Heifer International 2014a p. 3). Farmer livelihoods are also improved via direct income increases, by training farmer organizations and hubs to negotiate for better prices and contracts with dairy processors (Heifer International 2014a p. 4).

Resilience

Many smallholders rely on grazing to feed their livestock, but while this feed method has a low cost, it is vulnerable to seasonal weather patterns (TechnoServe Kenya 2008 p. 3). Having multiple sources of livestock feed through fodder source diversification helps improve livestock system resilience, by providing a backup in case the feed-stock is lowered due to climate-induced supply shocks. Incorporating agroforestry practices can help diversify the fodder source, and also helps stabilize ecosystem services, improving the soil's ability to retain water and thereby be more resilient to dry periods.

Mitigation

By reducing the number of cattle while increasing productivity, emissions per unit of milk are decreased. The use of improved manure management within the programme also limits methane emissions.

Other co-benefits

All major benefits fall under CSA.

Economic costs and benefits

Phase I of EADD earned local farming families more than USD 131 million, over approximately 94 million gallons of milk, while saving USD 11 million on financial services (Heifer International 2014a p. 2). An investment of USD 50 million financed Phase I. Farmers now earn an estimate USD 0.3 per litre of milk delivered, an increase of 50% compared to 2008 (Technoserve, 2014)

The counterfactual scenario to EADD is free-grazing or semi-grazing livestock systems, which have lower feed costs but require more labour per unit due to lower yields (TechnoServe Kenya 2008 p. 17). But while these systems can have good milk yields during the rainy season, due to the abundant pastures, there is a deficit in the dry season, leading to a shortage in supply (TechnoServe Kenya 2008 p. 18). Furthermore, the market cannot properly absorb the plentiful milk supply in the rainy season, leading to wastage and lost revenue. The only way for such production systems to increase profits is by increasing the number of livestock, which in turns increases competition for limited pasture, further constraining yields (TechnoServe Kenya 2008 p. 19). Despite having no input costs other than minimum labour salary and basic veterinary costs, annual revenues for a farmer who has four cows with are below the poverty line (TechnoServe Kenya 2008 p. 18). This puts farmers in a poverty trap, as low production yields low incomes, which constrain investments into further productivity increases.

Barriers to adoption

The practices associated with EADD have their own barriers to adoption and constraints. For improved manure management, lack of knowledge can be a barrier to proper management, as well as the requirement for additional labour if livestock is free roaming (Wambugu et al. 2014 p. 9). For improved feed practices, knowledge is a constraint, as well as access to seed and planting material for improved grasses such as Napier grass (Wambugu et al. 2014 p. 9). Purchasing commercial concentrates is costly, preventing resource-poor smallholders from gaining access. Livestock genetic improvement has perhaps the most considerable barriers, requiring knowledge, additional labour and capital (Wambugu et al. 2014 p. 9).

Key factors to success

The programme has successfully scaled-up climate-smart dairy practices through knowledge sharing, facilitated by the development of dairy producer associations. Knowledge and awareness were key success factors for several elements of the EADD. For improved manure management, training on best practices for handling and using manure to improve soil fertility needs to take place, providing information on which crops can be grown using the manure (Wambugu et al. 2014 p. 14). For improved livestock feed, the use of herbaceous legumes, fodder shrubs and crop residues should be encouraged, as well as the creation of cheap home-made rations (Wambugu et al. 2014 p. 20).

Gender and social inequality

Phase II of the EADD has the goal of increasing the number of women supplying milk by 30%. This is to be accomplished by training both men and women in gender equity, to help women express their needs and gain new respect within their community (Heifer International 2014a p. 8). Women and youth will be trained in business and farm skills to develop their self-reliance (Heifer International 2014a p. 8).

Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)

Livestock production has long been linked to deforestation, overgrazing, and GHG emissions from enteric fermentation. In Latin America, cattle production is especially abundant, occupying more than 33% of the region (Pagiola and Arcenas 2013 p. 1). Costa Rica, Colombia and Nicaragua are no exception, with cattle production driving deforestation, the loss of biodiversity and natural habitats (Pagiola and Arcenas 2013 p. 1). Although the expansion of livestock production has brought short-term gains, in the long-run, soil fertility and grass coverage are reduced, leading to degradation, air pollution, and contaminated water supplies (Pagiola and Arcenas 2013 p. 1).

To circumvent further negative impacts from livestock production and rehabilitate degraded lands, the Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP) ran from 2002 to 2007 in these three Latin American countries, spearheaded by local NGOs and the World Bank. The project entailed an integrated payment for ecosystem services (PES) scheme, which aimed to incentivise farmers to shift to silvopastoral practices in degraded lands (Pagiola and Arcenas 2013 .p 2). Silvopastoral systems involve the introduction of trees in livestock systems, providing multiple CSA benefits.

Benefits in terms of productivity, resilience and mitigation

RISEMP contributes to all three CSA pillars.

Productivity

Farmers participating in the PES scheme received an average of USD 580 per farm (Porras and Neves 2006 p. 2). In addition, farm productivity increased 5% for participating farmers (Porras and Neves 2006 p. 2). Milk production increased due to improved feeding and shade from trees (Porras and Neves 2006 p. 2). Also, fewer pesticides and fertilizers were required in the silvopastoral systems, reducing input costs and increasing profits (Porras and Neves 2006 p. 2). However, it can take between 2 to 4 years for silvopastoral practices to become more profitable than current practices (World Bank 2008 p. 42).

Resilience

After trees have grown sufficiently in silvopastoral systems, less irrigation water is needed, providing greater resilience to drought conditions (Porras and Neves 2006 p. 2). By 2004, there was a 46% reduction in the area of degraded pastures (Porras and Neves 2006 p. 3).

Mitigation

The silvopastoral practices disseminated through the project had substantial carbon sequestration contributions (World Bank 2008 p. 18). This took place directly, through the trees incorporated in livestock production, and indirectly, through reduced applications of nitrogen fertilizers, and reduced methane emissions from improved livestock feed (World Bank 2008 p. 18). By 2004, 15,600 tonnes of carbon had been sequestered (Porras and Neves 2006 p. 2).

Other co-benefits

The project brought forth increases in biodiversity in participating areas, including forest-dependent and endangered species (World Bank 2008 p. 18). The project was also successful in impacting policymaker decision-making in several Latin American countries, including Colombia and Ecuador (World Bank 2008 p. 42).

Economic costs and benefits

Total project cost was USD 11.54 million (World Bank 2008 p. 21). The initial investment costs for implementing silvopastoral practices are high for farmers, for example p. establishing protein banks (USD 960/ha); live fencing (USD 700/ha); planting 100 trees in pastures (USD 55/ha). But after trees have grown there are notable economic benefits.

An initial analysis of the financial returns on different silvopastoral farm models included in the three countries indicated marginal profitability in almost all cases (World Bank 2008 p. 27). But without PES, the high initial investment and labour costs gave an IRR lower than the opportunity cost of capital (World Bank 2008 p. 27). Follow-up analysis towards the end of the project's run in Costa Rica indicated higher numbers, with IRR ranging between 14% to 37%, depending on the combination of silvopastoral practices applied (World Bank 2008 p. 27-28). Again, high IRR values were conditional on PES in most cases (World Bank 2008 p. 28).

Barriers to adoption

Despite the long-term gains for farmers, initial investment and labour costs were potential disincentives to the adoption of certain silvopastoral practices (World Bank 2008 p. 27). Additionally, some of the silvopastoral practices that are most beneficial in terms of biodiversity are not as attractive to farmers (World Bank 2008 p. 18). The most attractive practices, such as intensive leucaena, only reap biodiversity rewards if established in conjunction with multi-species live fences (World Bank 2008 p. 18).

The project ran the risk of providing perverse incentives, due to the design of the PES scheme. As farmers received payments based on marginal improvement on land use, there was potential for motivating farmers to intentionally degrade their land, in order to reap higher payments (Pagiola and Arcenas 2013 p. 5). To circumvent this, a ban on pasture burning and deforestation of primary and secondary growth forests were imposed (Pagiola and Arcenas 2013 p. 5).

Key factors to success

Some key methodological strategies for implementing the project drove its success. Empowering and training farmers to become the voice of the project resulted in greater adoption of silvopastoral practices (World Bank 2008 p. 19). Developing appropriate indicators for e.g. biodiversity and carbon values in different land uses, and communicating them in a manner which farmers can quickly comprehend, were crucial to help farmers relate their activities to a specific level of compensation (World Bank 2008 p. 18-19). Knowing the level of compensation and ability to choose from different land uses made farmers more comfortable with adopting new practices.

To overcome the initial investment barrier, small upfront payments were issued to participating landowners (Pagiola and Arcenas, 2013 p. 5). In order to motivate the adoption of practices with higher biodiversity and sequestration values, short-term payments can be issued to the more productivity-oriented practices, with long-term payouts for practices that are more oriented towards mitigation and resilience (World Bank 2008 p. 42).

Gender and social inequality

This project had no specific gender component.

5. Policies and Programs

Productive Safety Net Programme (PSNP) in Ethiopia

Smallholder farmers account for three-quarters of Ethiopia's population, and are particularly vulnerable to climatic variations, which will likely worsen in the long-term (Neate 2013 p. 23). Ethiopia has suffered through countless droughts and famines throughout the past century, and the droughts are only becoming more and more frequent (Neate 2013 p. 23). Ethiopian smallholders survive from harvest to harvest, and just one failed yield can force farmers to sell off their assets just to avoid starvation (Neate 2013 p. 23). Often, humanitarian aid responses to such crises are delayed and potentially inappropriate (Hobson & Campbell, 2012). To provide a more effective response to this critical situation, the Government of Ethiopia introduced the Productive Safety Net Programme (PSNP) in 2005, with the aim of improving food security through government transfers directed towards people who are exposed to chronic food shortages and drought. By setting up effective systems before crises hit, the PSNP is able to respond in as little as two months, compared to the usual eight month response time of conventional aid systems (Hobson & Campbell, 2012).

The Government of Ethiopia is spearheading the initiative, with funding from external donors including the World Bank World Food Programme, the European Union, and various nations. PSNP provides cash and/or food payments to households that have experienced food shortages for a minimum of three months each year in the previous three years, and have no other safety net (e.g., family members working in towns who send remittances) (Neate 2013 p. 23). In exchange for the assistance from PSNP, households are to work on public works projects for six months; if households cannot provide labour, they receive the transfers as grants. The public works projects are intended to be sustainable community assets, which can build resilience, rehabilitate degraded lands, and increase productivity (World Bank 2013 p. 2). Alongside the PSNP, the Household Asset Building programme (HABP) has been established to help provide agricultural credit and access to services to increase production. Since its inception, the program reached 7.6 million beneficiaries by 2012 (World Bank 2013 p. 2).

Benefits in terms of productivity, resilience and mitigation

PSNP contributes mainly to productivity and resilience, but offer the potential for mitigation gains as well.

Productivity

In addition to direct contributions to food security, the public works aspect of the PSNP brings further productivity and income benefits. Approximately 60% of the PSNP's public works projects are related to soil and water conservation. These projects have resulted in increased wood and vegetation cover, contributing increased stocks of livestock feed, medicinal plants and bee forage, providing additional income sources and savings (World Bank 2013 p. 5). Further projects involve small-scale irrigation, which has helped 4-12% of households expand their livestock holdings, in turn increasing incomes by 4-25% (World Bank 2013 p. 5). Water conservation structures have also been constructed through the public works program, reducing surface runoff while increasing infiltration and ground water levels, leading to increased yields (World Bank 2013 p. 5).

Resilience

Public works projects under PSNP create community assets which can reverse watershed degradation, and increase the reliability of the water supply, even under different climatic conditions (World Bank 2013 p. 5). The PSNP offers significant improvements to the coordination and management of natural resources and hazard events, including early warning information from the Early Warning and Response Directorate.

A Risk Financing Mechanism (RFM) and contingency budget have also been established through the PSNP, protecting income and assets built up through the project from climatic shocks (World Bank 2013 p. 2). The contingency budget serves to respond quickly to food needs during crisis, and has been shown to have some advantages compared to traditional humanitarian responses (World Bank 2013 p. 7). When the contingency budget has been exhausted, the RFM can step into force and scale up to meet the needs of the crisis, providing assistance to households before the shock is felt (Hobson & Campbell, 2012)

Mitigation

While several reports have indicated that the public works projects have potential to sequester above and below ground carbon, there is a lack of estimations or measurements on the exact impact of these projects (Cooper et al. 2013 p. 69-70).

Other co-benefits

There is evidence that PSNP and HABP contribute to tree planting (Neate 2013 p. 25). Some public works projects, e.g. road construction, can have multiple non-CSA benefits, such as access to education, medical care, etc.

Economic costs and benefits

The 2010 project budget was an estimated USD 347 million, with a cost per beneficiary of USD 47 (Stirk, 2012). In the same year, a survey of PSNP households indicated that 70% of PSNP households perceived their economic condition to be better or the same as the previous year, compared to 41% in 2008 (Cooper et al. 2013 p. 68). While data is lacking for the cost-benefit of the entire project, there are cost-benefit ratios available for individual public works projects. For soil and water conservation projects, including e.g. their contribution to wood and forage production and soil loss reduction, there is an average cost-benefit ratio of 1.8 (World Bank 2013 p. 5).

Barriers to adoption

Despite specific aims to include women into the PSNP, some female household members have difficulties striking a balance between household tasks and

participating in the public works programs, and are less likely to have contact with development agents and have access to credit (World Bank 2013 p. 6).
There have been some shortcomings to the RFM, including time lag from the generation of initial early warning data and converting this information into relief action (World Bank 2013 p. 8). Better training and guidance for the management of the RFM process itself are mandatory to improve coordination and crisis response (World Bank 2013 p. 8).

The level of PSNP population coverage has also been criticised for being too exclusive. A 2011 impact evaluation demonstrated that many non-beneficiaries were experiencing food shortages, indicating a high level of exclusion error (World Bank 2013 p. 10).

Key success factors

The inclusion of the public works activities within PSNP provides a dual return on investment, by improving resilience and livelihoods. Ensuring the quality and sustainability of the public works is essential to make sure that these improvements will provide lasting productivity and resilience benefits (World Bank 2013 p. 16-17). According to regional officials, the projects that provide the most support for livelihoods are the construction of roads, rock dams and enclosures for growing fodder trees, as well as terracing, and tree planting (Cooper et al. 2013 p. 69).

Gender and social inequality

Within the PSNP, special regard is taken to the gender-specific vulnerabilities of women, to ensure the inclusion of women. Community day care facilities have been established to allow women with small children to work, in addition to more flexible working terms for women to allow them to fulfil their domestic responsibilities (World Bank 2013 p. 6). Women make up 25-53% of direct beneficiaries in each participating region (World Bank 2013 p. 6). The program has also been shown to reduce anxiety, smooth consumption patterns, provide basic necessitates and drive school enrolment for women and their families (Cooper et al. 2013 p. 68).

National agroforestry policy of India

Over 80% of India’s farmers are rainfed smallholders, who cultivate on two hectares of land or less, making them highly vulnerable to the negative impacts of climate change. Agroforestry, which entails incorporating trees and shrubs into farmlands and rural landscape, provides an opportunity for farmers to improve their productivity and resilience while contributing to increased tree coverage. In 2014, the Government of India launched an ambitious National Agroforestry Policy to mainstream tree growing on farms, a world first. The policy aims to create convergence between various programs, schemes and agencies containing agroforestry elements, in order to enhance the productivity, income and livelihoods of smallholder farmers (Government of India 2014 p. 5). The policy also aims to help meet the increasing demand for agroforestry products such as timber, food, fuel, etc., protecting the environment and natural forests, and minimizing the risk during extreme climatic events (Government of India 2014 p. 5). Since the policy was adopted in 2014, grants have been provided to six states and will cover approximately 70,000 ha in agroforestry (ICRAF 2014 p. 125).

Benefits in terms of productivity, resilience and mitigation

Agroforestry contributes to all three CSA pillars.

Productivity

Agroforestry brings productivity gains alongside poverty reductions through improved income sources (Chavan et al. 2015 p. 1828). Using fertilizer trees can improve soil fertility, bringing productivity gains (Pye-Smith 2008 p. 21). The trees themselves provide fruits which can be consumed or sold, improving diets and/or incomes. Additionally, agricultural incomes can be supplemented through the increased production of wood products, which can be sold or used within farming households.

Resilience

Ecosystem services provided by agroforestry can provide resilience benefits to smallholder farmers. In the short-run, agroforestry can damped the effects of climate change through microclimate moderation and the conservation of natural resources (Government of India 2014 p. 1). In addition, agroforestry systems provide valuable ecosystem services such as improved soil fertility (Chavan et al. 2015 p. 1832)

Mitigation

In the long run, agroforestry provides a source of carbon sequestration. Compared to crop and grass systems, agroforestry species provide far more carbon sequestration potential, on par with primary forests (Government of India 2014 p. 1). Agroforestry systems sequester between 0.5 to 2.0 Mg/ha of carbon annually (Chavan et al. 2015 p. 1832).

Other co-benefits

A large-scale increase in agroforestry has the potential to provide employment opportunities for both rural and urban populations through industrial application, production, and value addition. Currently, timber production on farms generates 450 employment-days per hectare per year (Langford, 2014). There is also the potential for augmenting the energy supply through biomass production.

Economic costs and benefits

An investment of USD 30-40 million has been attached to the policy (Langford, 2014).

Barriers to adoption

The key challenge of this policy, is how to properly implement it to have an impact at the field-level (Chavan et al. 2015 p. 1834). Several pre-existing legal, institutional and other factors have hindered the adoption of agroforestry among farmers in India. Although farmers are interesting in expanding into agroforestry, there are many missed opportunities for providing incentives. For example, India had highly restrictive rules for harvesting and transporting trees planted on farms, as well as use of non-timber produce. Additionally, agroforestry development lacked extension and institutional support mechanisms, and suitable research on suitable agroforestry models across regions. A dearth of sufficient quality planting materials and post-harvest technologies has also impeded agroforestry growth. (Government of India, 2014 p. 2)

In addition to the complicated legal environment, farmers have also been hesitant to adopt agroforestry practices due to apprehensions about long rotations, and reductions in growing area (Chavan et al. 2015 p. 1827).

Key factors to success

The project has been driven forward through early and continuous engagement with governmental and NGO partners. Coordination and convergence across ministries and schemes is necessary to drive agroforestry systematically, bringing together the patchwork agroforestry policies and programs (Government of India 2014 p. 2). Throughout the policy making process, a large number of stakeholders contributed technical information from their specific interest areas, including the Ministry of Agriculture and various departments, State Governments, industry, and educational and research institutions (ICRAF 2014 p. 126).

To make suitable agroforestry approachable for farmers, it is imperative to provide an integrated farming systems approach comprised of a portfolio of activities, rather than a one-size fits all model (Government of India 2014 p. 3). The awareness and availability of finance and insurance schemes must be improved, as they will help encourage farmers to take up agroforestry (Chavan et al. 2015 p. 1831). But as the policy is drafted now, there is a lack of clarity regarding exactly how this is to be achieved (Chavan et al. 2015 p. 1831). Bankable agroforestry projects need to be formulated, as well as an expansion of specific schemes such as tree insurance (Chavan et al. 2015 p. 1831).

Gender and social inequality

The policy has no specific gender component.

Climate and the Colombian Agriculture Sector: Adaptation for a Productive Sustainability

An agreement between the Colombian Ministry of Agriculture and Rural Development (MADR) and the International Center for Tropical Agriculture (CIAT), supported by CCAFS, seeks to enhance the competitiveness of the Colombian agricultural sector through the implementation of policy instruments, strengthening the investment of resources for research, technological development and innovation. For the first time in Colombia, the project brings together national government, academia, research centers, NGOs and farmers in different crops production chains (CCAFS, 2015).

This collaboration consists of four actions that seek to strengthen the resilience of agriculture to climate variability and change and improve the efficiency of resource use in production systems in priority regions: i) Modelling and agroclimatic forecasts to support short and long term farmer decision making processes; ii) Climate-Site Specific Management as a tool to determine the most limiting factors associated with variation in productivity, in order to increase productivity; iii) Technological options for adaptation in priority crops as one of the adaptation measures in terms of developing new and more resistant varieties to climate change; and iv) Environmentally sustainable production systems seeking to reduce negative impacts on natural resources while increasing productivity in crops. Throughout the process, Colombian Farmers' Organizations are being empowered with scientific tools and resources.

Benefits in terms of productivity, resilience and mitigation

The project contributes significantly to all three CSA objectives.

Productivity

The project includes varietal evaluation within context of both climate variability and change, seasonal agroclimatic forecasting, and climate site-specific management systems as a tool to determine the most limiting factors associated with variation in productivity, in order to increase it. Scientists were responsible for calibrating a range of varieties, generating seasonal agroclimatic forecasts, and analysing historical records. The project implements suitable sites for planting specific crops, selecting the best suited to each climate and soil condition and implementing major management practices to reach high yields. About 2,000 farmers are currently implementing these practices, mostly based on best varieties and planting dates at site-specific level. The approach implemented in Colombia has the potential in the mid-term of having about 700,000 farmers implementing high-yield practices.

Resilience

The project aims to support agriculture in adapting to climate phenomena, including long-term adaptive strategies and climate risk management by evaluating and validating crop models through modelling and agroclimatic forecasts and to develop new germplasm to better respond to changes in climate. With the help of farmer's organizations, scientists are trying these new genotypes in different environments to offer an alternative to farmers (This research also contributes to data modelling activities aimed at estimating the vulnerability of each crop to the impacts of climate change. Currently the project reaches about 500,000 growers through a platform for information management and knowledge called Agronet. One of the key strategies to disseminate agroclimatic information useful for farmers' decision making process consists in reaching the farmers across Colombia through mechanisms such as the release of agroclimatic newsletters by MADR.

Mitigation

In terms of mitigation contributions, the component on environmentally sustainable production systems aims to determine the water and carbon footprint for different crops in different regions of the country, taking into account diverse crop management practices. It intends to identify those practices that minimize impacts of climate change without damaging the crop productivity, which serve as an opportunity for the development of incentives aimed at the conservation of ecosystem services.. The studies within this component provide technical information to be used as input in sectorial discussions on alternatives for low emissions agricultural production such as reconversion of livestock production in Colombia. Specifically, the agreement is helping the government to formulate a Nationally Appropriate Mitigation Action (NAMA) for the livestock sector including the quantification of GHG and an analysis of barriers of implementation for the different mitigation measures proposed.

Other co-benefits

Institutional strengthening and capacity building are clear benefits from this project, since the national farmers' organizations are receiving and understanding different methods, methodologies and technologies jointly produced within the project. That capacity is being integrated by each organization and expanded within their institutional structure. The MADR is also benefiting from both the institutional strengthening and capacity building since now farmers' organizations have more tools to help farmers to face climate change and variability impacts and therefore it reduces costs for the MADR to help farmers once the climate event has occurred. The Colombian experience on addressing climate and variability impacts in agricultural sector has been taken as an example not only for other countries within Latin America such as Honduras but also it has promoted South-South exchange with African countries such as Senegal (CCAFS, 2013, 2014) through the involvement of Colombia's Presidential Agency for International Cooperation (APC) (CCAFS, 2014a).

Economic costs and benefits

By the end of the project, it is expected an incremental contribution in rice (3 ton/ha), beans (0.5 ton/ha) and cassava (2 ton/ha) production which means a potential value of USD 152 million per year in total. The project is seeking to avoid 30% of total losses in crops such as rice and maize due to climate variability, which is equivalent to USD 50 million approximately. By increasing resilience of Colombian agricultural sector, production gap is expected to be reduced by at least 50%, saving resources equivalent to investments used to feed about 4 million of the Colombian population.

Barriers to adoption

At the beginning of the project, the language of the agroclimatic newsletters was too technical for some of the farmers. There were difficulties in gaining credibility with national farmers' organizations, and a lack of understanding of the tools proposed. In addition, national farmers' organizations neither cover all farmers in all producing regions nor know in detail growers' situations in all of the regions.

Key success factors

A key success factor was the articulation since the very beginning of the project with the relevant stakeholders in the agricultural sector, such as the MADR and key national farmers' organizations. For these institutions, addressing the impacts of climate change in the agricultural sector became a relevant matter and they were willing to develop a joint strategy to benefit farmers and rural families. Additionally, the success was possible given that the challenges or barriers mentioned above were overcome by adopting different strategies: 1)

Credibility from national farmers' organizations was gained through adaptation strategies presented as a combination of methods to address climate change challenges rather that a "shopping list" of tools/methods. In terms of the analysis of historical information, both benefits and capabilities of using the tools, were demonstrated in order to gain credibility with data owners and encourage them to share more information; 2) To increase the coverage of more farmers in more producing regions, alliances with other either public or private institutions were consolidated, and at the same time, scientists worked closely with technicians in the regions; and 3) Adaptation of language to local understanding of agroclimatic newsletters was needed to bridge the gap between meteorologists, agronomists, modellers and practitioners.

Gender and social equality

The agreement has no specific gender component.

6. Services

Climate seasonal forecasts within the cowpea sector in Burkina Faso

Within Sahelian climatic zones, farmers are heavily exposed to climate variability. In particular, Burkina Faso is highly dependent on agro-climatic factors such as rainfall, temperature and wind, which are undergoing major alterations due to climate change (Somda et al. 2014 p. 13). As a result, food security is becoming increasingly problematic, particularly amongst rural populations, where adaptive capacity is limited and where reductions in yield and gross agricultural margins are the most pronounced. Improving farmers' ability to understand, monitor and predict climate variability through climate information services can allow them to make informed decisions of how to minimize losses during climatic downswings, while taking advantage of opportunities provided during upswings.

In order to understand the precise benefits of these services, CCAFS initiated a collaborative research project with the Institute for Environmental and Agricultural Research (INERA) and Projet d'Appui aux Filieres Agricoles (PROFIL) to study the climate-smartness of seasonal climate forecasts, in terms of their impact on the productivity and resilience of cowpea farmers in the region. To assess the benefits of using seasonal climate forecasts, the study compared two groups: an experimental group of farmers who received climate information and agro-advisories, and a control group of farmers who did not receive any climate information.

Benefits in terms of productivity, resilience and mitigation

This project seeks to enhance productivity and resilience through improved seasonal forecasts.

Productivity

It was found that farmers using climate information were more productive than non-users across both agricultural sectors. Climate information was found to have an impact on the inputs applied by cowpea farmers, who were more likely to use more fertilizers and improved seeds (Ouédraogo et al. 2014 p.103). In addition, productivity was enhanced due to advice on better resource allocation delivered through the climate information services (RPL WA, 2014 p. 30). For seasonal forecast users achieved average yields of 660 kg/ha, compared to average yields of 561 kg/ha for non-users (RPL WA p. 29).

Resilience

Using seasonal forecasts improved farmer incomes as well as their resilience to climate change, by reducing the losses normally caused by climate variability.

Mitigation

Climate information does not explicitly provide mitigation benefits.

Other co-benefits

All major benefits fall under CSA components.

Economic costs and benefits

Climate information provided increases in added value for cowpea production, as demonstrated in Table 6. Within cowpea production, climate information users received an additional USD 30/ha in added value compared to the control group (RPL WA p. 30). Cowpea producers who had been exposed to climate information were able to obtain higher yields at a lower input cost.

Table 6. Difference in added value between receivers of climate information and control group

	Added value (test	Added value	Difference in added

	group)	(control group)	value
Cowpea production	USD 297/ha	USD 267/ha	USD 30/ha

Barriers to adoption

In general, there are several constraints which can potentially limit African farmers' utilization of climate information for agricultural risk management. Barriers include the degree to which forecast parameters actually correspond to the needs of farmers, the availability of alternate management options and sufficient resources to implement them, as well as the challenge of translating and delivering forecasts to farmers (Roncoli et al. 2011 p. 124).

Key success factors

For climate information services to be successful, it is imperative to understand the socioeconomic factors that can inhibit access. Special attention must be paid to how women access information, as well as the type of information they seek (McOmber et al. 2013 p. 41). General success factors include interaction between farmers, agricultural organisations and climate forecasters, delivery and local scale, and giving farmers an effective co-production voice within the design and implementation of climate services (Tall et al. 2014 p. 5). Participatory approaches are especially effective at identifying the best forms of communication forms and information that fit a given location (Tall et al. 2014 p. 5).

Gender and social inequality

The project intends to address the needs of both women and men farmers from each agricultural sector who participate (RPL WA 2014 p. 2).

Communicating seasonal forecasts to farmers in Senegal for better agricultural management

At the global level, approximately 80% of agricultural production is rainfed, rendering it vulnerable to climate variations and extreme weather (Tall et al. 2014 p. 6). Despite a wealth of traditional knowledge and coping mechanisms, increasingly rapid and erratic climate conditions have tested the limits of smallholder farmers' ability to adapt to their environment (Tall et al. 2014 p. 6). To remedy this, climate information services can supplement smallholders' knowledge base, providing insights which can boost farmer decision-making and risk management skills, despite increasing uncertainty. Climate services include the provision of relevant weather and climate information, as well as advisory services which help farmers act on the information received (Tall et al. 2014 p. 7).

Starting in 2011, CCAFS has been engaged in a climate services pilot project which has been extended from the peanut basin of central Senegal to cover the entire Kaffrine region. Temperature increases and rainfall decreases have been projected for the Kaffrine region, where most of the population is dependent on agriculture and pastoralism, creating a need for further adaptation measures (Ndiaye et al. 2013 p. 1). The aim of the project is to translate and communicate seasonal forecasts in simple, understandable language which can assist farmers in making crucial management decisions, facilitated by discussions of traditional forecasts practices which allow farmers to share their different types of knowledge (Ndiaye et al. 2013 p. 1). Beginning in 2014, CCAFS has partnered with the national meteorological agency, broadcasting 10 day forecasts through the rainy season to nearly 4 million farmers (Lo and Dieng 2015 p. 37).

Benefits in terms of productivity, resilience and mitigation

The program aims to provide productivity and resilience benefits, but does not have any explicit contribution to mitigation.

Productivity

The most significant impact of improved seasonal forecasts for farmers in Senegal was the increase in agricultural yields (Lo and Dieng 2015 p. 48). To test yield increases, the program created test farms which strictly applied forecasts and related agricultural advice, and compared them with control farms using traditional methods. Comparable data was available for souna and groundnut flower, indicating 50% and 15% increases in yields respectively, as shown in Table 7.

Table 7. Comparison of yields between test farms receiving climate seasonal forecasts and control farms (Adapted from Lo and Dieng 2014 p. 48)

Crop Type	**Control Farm**		**Test Farm**		
	Quantity Sown	Quantity Harvested	Quantity Sown	Quantity Harvested	Difference in yield
Souna 3	1 kg	370 kg	1 kg	555 kg	+185 kg
Groundnut Flower 73	40 kg	780 kg	40 kg	900 kg	+120 kg

Resilience

The seasonal and 10-day forecasts allow farmers to adjust their decisions at short notice, such as the timing of planting, to cope with increasing rainfall variability.

Yield increases in turn improved household incomes, providing a safety net for leaner production periods (Lo and Dieng 2015 p. 49).

Mitigation

No mitigation benefits are specifically provided through the project.

Economic costs and benefits

Cost-benefit analysis of providing climate information for smallholder farmers is lacking from this project. Benefits could potentially be estimated by calculating the increases in net income derived from yield increases outlined above, as well as the avoided losses based on good climate information (Feinstein 2014 p. 17). The large user-base indicates that it is implicitly cost-effective.

Other co-benefits

In addition to the productivity and resilience improvements for farmers receiving forecasts, the project helped develop the institutional capacities of the national meteorological agency.

Barriers to adoption

A considerable barrier to overcome is the challenge of communicating the complex probabilistic aspect of seasonal forecasts in a simple manner that can be understood by farmers. Furthermore, lack of sufficient access to land is a significant constraint, especially for women farmers (Lo and Dieng 2015 p. 54). Despite the fact that they had access to climate information and advice, many women did not have land upon which they could apply their knowledge. Discrimination against women in the distribution of land and seeds was attributed to the link between payment of the rural tax and access to seeds (Lo and Dieng 2015 p. 54).

Key success factors

The primary success factor for this case is the partnership with the national meteorological agency, the Senegal Agricultural Research Institute and the Ministry of Agricultural and Extension Services, in addition to local radio stations, who all contributed to producing, communicating and adding value to climate information (Tall et al. 2014 p. 22). In addition to these partnerships, climate services require sustained engagement and effective communication with their user base in order to properly understand their needs, and incorporate farmers into the design and evaluation process of products and services (Tall et al. 2014 p. 7). The interactive nature of the radio programs was highly successful, allowing the program to scale up. Blending local knowledge with scientific knowledge not only improves the robustness of the information provided, but it also increases forecast uptake (Feinstein 2014 p. 7).

To facilitate this process, it was important to build trust and mutual learning between farmers and extension workers (Ndiaye et al. 2013 p. 4).

Choosing the right vehicle for getting forecasts out to farmers is another key step. While rural radio is an obvious choice, the signal can be weak while the farmers are in the field (Ndiaye et al. 2013 p. 3). Again, consulting with climate information users and using a combination of channels (e.g. radio, SMS, television) can ensure that effective lines of communication are established.

Furthermore, climate information services are reliant on several additional factors, if crop success and yield increases are to be achieved. The availability of a good variety map is crucial, as well as the accessibility and availability of good quality seeds, delivered on time in sufficient quantities (Lo and Dieng 2015 p. 54).

Gender and social inequality

The program had a specific sensitivity to gender issues, and found marked differences between men and women's access to climate information services, as well as the type of information they required. More specifically, there are gender-based differences in how farmers are most likely to receive climate information, with women generally receiving information through direct personal contacts over formal channels (Ndiaye et al. 2013 p. 3). These differences are often related to the division of labour, where women are often busy during the time of day where forecasts are broadcasted on the radio (Twyman et al. 2014 p. 27).

African Risk Capacity (ARC) Facility

In sub-Saharan Africa, there is missed potential in coordinated response to food crises such as drought. Funding is typically provided on an ad-hoc basis, taking place after crisis has occurred. This time lag leads to slow response times to crises, furthering loss of assets and livelihoods at best, human life at worst.

In conjunction with the World Food Programme, the African Union Commission is working towards a pan-African drought risk facility. Namely, the African Risk Capacity (ARC), which aims to offer quick access to funds based on objective triggers, such as weather indices. Instead of relying on time-consuming and unreliable pleas for international assistance, the ARC brings in insurance elements to create a shared safety net between African nations. Member governments, and donors, are to make annual payments to the ARC fund, allowing governments to issue claims if weather indices indicate need for food security interventions.

Benefits in terms of productivity, resilience and mitigation

ARC contributes to the productivity and resilience objectives.

Productivity

The negative impact of drought upon farmers' livelihoods depends upon the severity and duration of the dry spell. Even short droughts can impact yields and incomes. This reduction in income may reduce the amount which farmers are able to invest into farm inputs for following growing seasons, thus extending the impact of the drought to the next harvest (Clarke and Hill 2013 p. 30). Additional coping strategies may include drawing down on household grain stocks, deferring sale of produce at market, consuming less food or lower quality food (Clarke and Hill 2013 p. 30). In severe cases, farmers may be forced to sell their non-productive assets to find cash for meeting basic food needs (Clarke and Hill 2013 p. 30). If drought continues in the long run, farmers will be forced to sell their productive assets (e.g. livestock or land) as well, significantly impacting their productivity in the future (Clarke and Hill 2013 p. 31). Providing insurance through ARC can help counter-act these negative impacts.

Resilience

ARC protects farmers and their assets from extreme climate events, improving resilience.

Mitigation

ARC has no direct mitigation benefits.

Other co-benefits

Although the exact impact has not yet been investigated, creating a sustainable cooperative insurance mechanism owned by African states may have additional political benefits (Clarke and Hill 2013 p. 3).

Economic costs and benefits

Initial capital costs are expected to be USD 150 million, paid for by donors (Clarke and Hill 2013 p. 6). At the most basic level, the benefit ARC provides is faster response times to crisis. Slow response times lead to the negative aspects listed above, namely unsustainable coping strategies, asset loss, reduced calorie intake and negative health outcomes. . Reduced consumption during early childhood leads to long-term losses in lifetime earnings (Clarke and Hill 2013 p. 36). Asset loss, livestock death, and consumption reductions further reduce growth at the macro level, and reduce household incomes at the micro level (Clarke and Hill 2013 p. 36). For each month of delayed crisis response, these impacts become increasingly costly on a per-household basis as time goes on. While costs of delayed response are negligible in the first three months, they rise to USD 49 per family after 4-5 months, and up to USD 1,294 per family between 6-9 months. Comparing several ARC scenarios to the baseline, additional benefits to poor households for each dollar spent range from 1.28 to 1.9, due to increased delivery speed and targeting (Clarke and Hill 2013 p. 44).

Barriers to adoption

One draw-back to this form of index-based insurance compared to traditional insurance is that there is an increased potential for basis-risk (Poole 2014 p. 7). This means that there may be a disconnect between losses calculated by the index and actual on-farm losses, causing some people who have been seriously affected by drought to not receive pay-out, or vice versa (Poole 2014 p. 7).

Key factors to success

The level of benefits resulting from ARC is similar to general principles of insurance. Benefits will most likely be higher if the insurance provided by ARC is for extreme climate events, rather than more common events (Clarke and Hill 2013 p. 3). For regular, smaller losses, other instruments should be used instead. Insurance must also be triggered by accurate indices which properly capture the impact of extreme climate events (Clarke and Hill 2013 p. 3). Costs of insurance must also not be too high, to ensure uptake. Benefits are largest when a large-scale and well-targeted safety net or government scheme exists, which can be adjusted quickly in times of need (Clarke and Hill 2013 p. 3).

Gender and social inequality

In long-lasting drought scenarios where household food consumption is reduced, the caloric intake of women is often the first to decline (Hoddinot, 2006 p. 315). By ensuring that household consumption levels stay stable even when crisis strikes, the health of women will be improved.

7. Value Chains

Effective Grain Storage Project (EGSP)

Traditional storage practices can leave staple grains vulnerable to pest infestations and grain pathogens, leading to 20-30% post-harvest losses (Tefera et al. 2011 p. 240). The threat of such heavy losses can push smallholder farmers into a poverty trap, where they are forced to sell their grain immediately due to the risk of spoilage, only to buy it back at a greater price a few months later (Tefera et al. 2011 p. 240). Additionally, pest attacks on stored grains have been linked to mycotoxin contaminations and poisoning, which render the grain unsafe for food and feed, further reducing food security (Tefera et al. 241).

While insecticides are frequently recommended to address pest outbreaks, they are often prohibitively expensive or unavailable to smallholder farmers (Tefera 2011 p. 241). Instead, hermetically sealed metal silos are a simple yet effective technology which can protect grains from invading insects, as well as rodents and birds. These metal silos are airtight, keeping out pests, keeping the grain safe for long periods of time.

To help bring the technology to smallholders and raise awareness within the policy environment, the International Maize and Wheat Improvement Center (CIMMYT) has recently launched the second phase (2012-2016) of the "Effective Grain Storage for Sustainable Livelihood of African Farmers" project in Zimbabwe and Zambia, with funding from the Swiss Agency for Development and Cooperation. Through improvements in grain storage technology, the project aims to bring reductions in post-harvest losses which can enhance food security, improve incomes, and reduce the vulnerability of resource-poor farmers.

Benefits in terms of productivity, resilience and mitigation

EGSP contributes to all three CSA objectives.

Productivity

Improved food storage not only increases agricultural resilience to pests, it has multiple benefits to productivity and farmer livelihoods. As ineffective grain storage contributes to significant post-harvest losses, reconciling this shortcoming can provide substantial gains to food security (Tefera et al. 2011 p. 242). Furthermore, when using traditional storage management technologies, farmers are often forced to sell their produce directly after harvest, resulting in low market prices for any surplus grain (Tefera et al. 2011 p. 240). Effective storage can improve agricultural incomes, by allowing farmers to hold their stocks and sell them when market conditions are most favourable (FAO 2008 p. 3).

Resilience

As the metal silo can store produce such as maize and bean for up to three years, farmers can put aside food reserves to prepare for climate change induced crop failures (Tefera et al. 2011 p. 242). EGSP also increases resilience to pests and diseases, which can spread as climatic conditions change.

Mitigation

Metal silo technology provides indirect mitigation benefits as well. By reducing post-harvest losses within a scarce food supply, improved storage improves food security without the need for increases in production. This can relieve pressure to expand the area under cultivation or utilize more intensive farming practices, which can both be environmentally taxing (Tefera et al. 2011 p. 243).

Other co-benefits

Fabrication of metal silos can help develop rural enterprises and create jobs (Tefera et al. 2011 p. 242). Demand for metal silos creates manufacturing activities for tinsmiths, creating extra seasonal income (Tefera et al. 2011 p. 243). In some cases, unemployed rural youth were hired to assist in the manufacturing process (CIMMYT 2011 p. 41).

Economic costs and benefits

Metal sheet, labour and transportation cover the main costs of metal silos, and these prices can vary from country to country. Half of the cost comes from the metal sheet alone, meaning that price per tonne decreases with volume. While small containers cost USD 322/tonne grain, containers up to 1.8 tonne have a price of only USD 178/tonne grain (CIMMYT 2011 p. 24). Beyond this point diminishing returns begin take effect, and operation of the container becomes increasing difficult. Cost benefit analysis covering the first phase of the project (2008-2011) shows promising results. Benefit was calculated based on the estimated storage loss avoided per year, valued USD 230/tonne, over a 15 year period, discounted at 10% (CIMMYT 2011 p. 24). Costs were calculated similarly, at an annual basis, discounted 10% as well. The resulting cost-benefit ratios indicated that cost-benefit ratios of 2.3 and 3.25 could be achieved for 0.7 and 1.8 tonne silos, respectively (CIMMYT 2011 p. 25). As a result, smaller metal silos storing less than one tonne may not be cost-effective (Renard & Storr 2011 p. 6).

Barriers to adoption

Similar to other agricultural technologies, the adoption of metal silos is heavily dependent on cost-effectiveness for farmers (Tefera et al. 2011 p. 244). Although this post-harvest storage technology is simple and effective, the high initial investment cost can constrain adoption amongst farmers (Tefera et al. 2011 p. 244).

Key success factors

To circumvent the economic barrier, innovative approaches must be applied to provide the means and incentives to ensure the adoption of this technology. For example, CIMMYT established a revolving fund to help finance the labour and material costs necessary for building metal sheets for the silos (Tefera et al. 2011 p. 244). Additionally, community training, demonstrations and participatory evaluations aided the rate of adoption, accompanied by subsidies to kick-start uptake during the initial phase of the project (Tefera et al. 2011 p. 244). While NGO involvement can drive this process in the short- and medium-term, increased private sector involvement is important to up-scale the technology in the long run (Tefera et al. 2011 p. 244). Establishing public-private partnerships can play an important role, but can provide further challenges in terms of navigating the diverse institutional interests involved (Tefera et al. 2011 p. 244).

The success of the technology also depends on the production's vulnerability to post-harvest losses, and market prices for grains. Sensitivity analysis of the phase one cost-benefit ratios indicate that the technology may not be cost effective if prices drop, or if losses due to pests are reduced (CIMMT, 2011 p. 26). If prices and losses both drop 50%, only the 1.8 tonne silos will break even (CIMMYT 2011 p. 26). Conversely, increased prices and losses will only increase cost-benefit ratios, with larger silos reaping the most gains.

Gender and social inequality

Women farmers are often the ones who are in charge of managing the metal silo content. As a result, improved storage has been shown to improve their status and self-esteem (Tefera et al. 2011 p. 242). Furthermore, the second phase of the EGSP program has made commitments to address gender equality in access to post-harvest technology, facilitated by a gender analysis currently being carried out across all EGSP countries (Renard and Storr 2013 p. 6).

African Leafy Vegetables (ALVs)

African Leafy Vegetables (ALVs) play an important role in poverty alleviation and food security, while carrying genetic traits which make them capable of withstanding climate related threats. Not only are they rich in vitamins and micronutrients, these hearty greens have been shown to contribute to the management of diseases such as HIV/AIDS, diabetes, and high blood pressure (FAO 2012 p. 55). However, in Kenya, the consumption and production of ALVs declined after the modernisation of agriculture and introduction of a market economy (FAO 2012 p. 55). A lack of consumer awareness and a poor product image dampened ALV demand, while a weak value chain and inefficient seed systems constrained ALV supply (Mwangi and Kimathi 2006 p. 2).

From 1996-2004, Bioversity International carried out the ALV programme in order to develop the production and consumption of ALVs, bringing them out from the shadow of obscurity. As a result, ALVs have become important commercial goods in Kenya, stepping out of the backstreets in the early 2000s, and have become increasingly popular in the formal market (Mwaura et al. 2013 p. 2). In the first phase of the project, quality seeds and training were introduced to peri-urban areas of Nairobi which drove the scaling up of smallholder ALV production. Next, an awareness campaign was launched within city supermarkets to promote nutritional value of the forgotten ALV varieties. Finally, through collective organisation, small scale ALV producers were able to gain the necessary business development services to successfully conduct business with the large supermarkets.

Benefits in terms of productivity, resilience and mitigation

The increased production and consumption of ALVs had a positive impact on food and nutritional security. Furthermore, ALVs themselves have several climate-smart attributes.

Productivity

Between 1997-2007, over 70% of farmers within peri-urban Nairobi had increased incomes derived from cultivating ALVs between, improving their ability to enter the market to meet food and other domestic needs (FAO 2012 p. 57-58). Furthermore, the affordability and increased supply of ALVs allowed poor people from rural and urban areas to increase their consumption levels, gaining the added food security bonus of ALVs' high nutritional content (FAO 2012 p. 58).

Resilience

Many ALVs have inherent resistances to pests and diseases (FAO 2012 p. 57), increasing farmer resilience to more frequent pest attacks brought on by climate change. Also, ALVs often have short growing periods, granting flexibility to farmers who cannot afford irrigation by allowing them to squeeze in a few crops during the rainy season, before the rains begin (FAO 2012 p. 57). Increasing biodiversity by promoting the cultivation of ALVs also allows for greater adaptation to variable environments, such as the alterations induced by climate change (Gotor and Irungu 2010 p. 42).

Mitigation

The built-in disease resistance of ALVs reduces the need for pesticide application, lowering GHG emissions.

Other co-benefits

Integrating small-scale ALVs farmers into the formal market has been shown to bring several non-CSA benefits. Overall human capital was developed through capacity building and training, leading to improved farming practices and business skills (FAO 2012 p. 57). Social capital was strengthened through project membership as well, leading to increased community participation, improved service delivery, and a reduction of moral hazard (FAO 2012 p. 57). Farmer access to credit increased as well, as farmers groups involved with the program were both able to start their own Savings and Credit schemes, and attract further micro-finance credit (FAO 2012 p. 58).

Economic costs and benefits

Assessing the cost-benefit of this project is a complicated endeavour, as agricultural biodiversity generates complex impact pathways which cannot be easily quantified in terms of yield increases or input efficiency (Gotor and Irungu 2010 .p 42-43). Costs and benefits related to biodiversity occur at different scales, and run the risk of spatial mismatch. While economic benefits related to increased biodiversity tend to be lowest at the local scale, and highest at the global scale, their costs are locally significant but only moderate at the global scale (Gotor and Inuru 2010 .p 43). However, a study of ALV farming in South-East Nigeria indicated healthy cost-benefit ratios due to their very low production costs. Cost-benefit ratios ranged from 2.07-4.50 across a variety of species (Agbugba and Thompson 2015 .p 34-41).

Barriers to adoption

Several factors hindered the market development of ALVs in Nairobi (FAO 2012 .p 57). Poor rural road infrastructure limited market place access for smallholders. A lack of government involvement and clear policy guidelines were another constraint. Guidelines for seed improvement, and distribution were also lacking. Furthermore, negative consumer perceptions regarding the sanitation of the ALV cultivation process n (i.e. using sewage water) held back demand in some cases. An impact assessment found that the poorest community members were lagging behind in ALV production and marketing (Gotor and Irungu 2010 .p 53). Lack of exposure to information on ALVs was a barrier for this group.

Key success factors

Both internal and external factors were key to driving the successful market penetration of smallholder ALV farmers. Internal to the farmers, although other project stakeholders helped improve the farmers' ability to organise themselves, there was already an underlying capacity for self-organisation and collective action (FAO 2012 .p 57). Without this foundation, the project would not have been successful. Many of the producers had previous experience growing ALVs, making it easy to convince them to increase production for the market. In fact, the longer farmers had been growing ALVs, the more likely they would get involved with marketing them (Gotor and Irungu 2010 .p 52). The education level of the head of household and their occupation (i.e., if they were already a farmer) were also found to be major determinants for the production of ALVs for markets (Gotor and Irungu 2010 p. 52). Farmer proximity to cities with large markets was important as well, giving comparative advantage to nearby farmers who were less exposed to crop-value loss due to deterioration from long transportation distances (FAO 2012 p. 57).

External to the farmers, there was a general awareness in Nairobi about diseases associated with poor diets, making it easier for dietary change to accommodate ALVs (FAO 2012 p. 57). Health experts began to recommend ALV consumption to the public as well, further boosting demand. Linkages were established with different farmers groups, NGOs and Supermarket chains, providing business support service, help with media promotional campaigns and research and development collaboration which all contributed to ALV market penetration (FAO 2012 p. 57).

Gender and social inequality

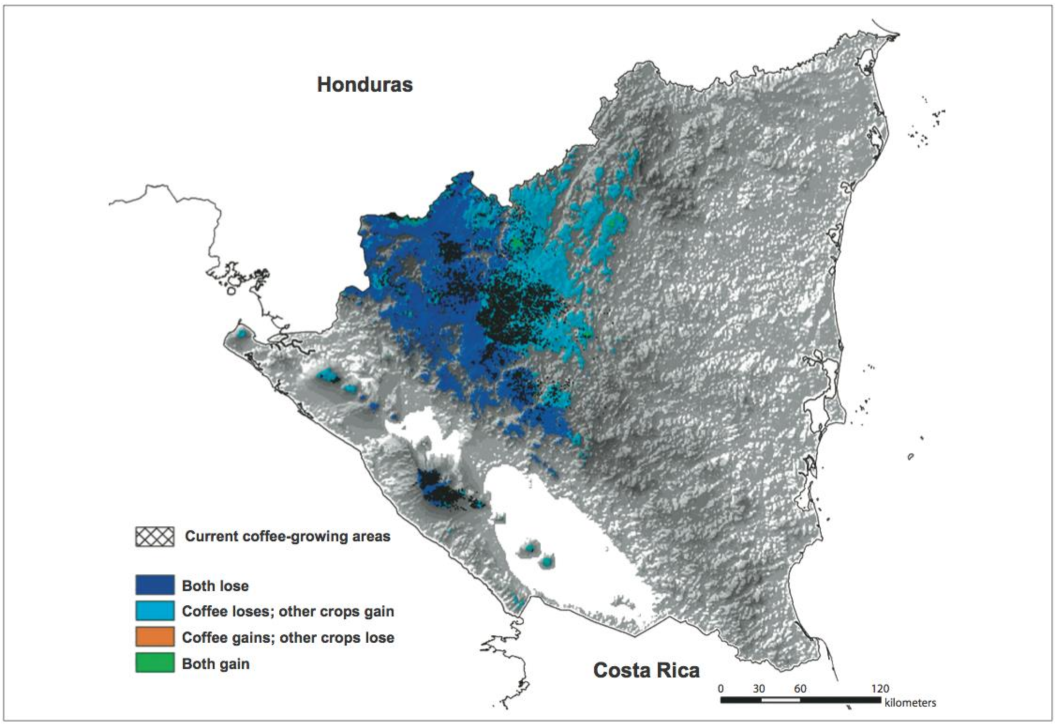
ALVs are traditionally grown by women farmers, and women continue to dominate their production and marketing (FAO 2012 p. 58). Developing the market for ALVs has had a positive impact on women’s incomes, and household food security (FAO 2012 p. 58). However, increasing commercialization is a potential threat which could undermine the role women play within the ALV sector. Women’s capacity could potentially be developed further, allowing them take a more prominent role in production and marketing (Gotor and Irungu 2010 p. 52-53).

Adapting to Markets and Climate Change Project in Nicaragua (NICADAPTA)

The agricultural sector of Nicaragua accounts for 20% of GDP and provides 29.5% of employment, making it vital to the country’s economy (IFAD 2013). However, Nicaragua is one of the most climate vulnerable countries in Latin America, and the performance of the agricultural sector is intrinsically linked to climate events (IFAD 2013). Despite progress in past decade, poverty remains a significant challenge for

Nicaragua as well, with overall poverty rates at 63.3% in rural areas (IFAD 2013 .p x). While coffee plays an important role, representing 20%-25% of the country's export revenues, projected increases in temperature and changes in rainfall patterns are expected to reduce the level of crop suitability in most of the areas where the crop is currently grown, as shown in Fig 2 (Läderach et al. 2013 .p 1).

Fig 2. Projected suitability of coffee and 30 other substitution crops in Nicaragua in 2050 (Läderach et al. 2013 .p 3)



To overcome these challenges, the NICADAPTA Project (Adapting to Markets and Climate Change Project) has been launched by the Government of Nicaragua, under the International Fund for Agricultural Development (IFAD)'s Adaptation for Smallholder Agriculture Programme (ASAP). The project facilitates productive investments, while providing technical assistance to smallholder coffee and cocoa farmers (IFAD 2013 .p vii). In addition, public institutions and policies are being strengthened to help climate-proof agricultural inputs, as well as the necessary incentives and climate information to facilitate smallholder adaptation (IFAD 2013 .p vii).

Benefits in terms of productivity, resilience and mitigation

NICADAPTA aims to contribute to all three CSA pillars.

Productivity

The project intends to increase both the incomes and productivity of families belonging to cooperatives with investment plans in place by 20% (IFAD 2013 .p xi). This will be accomplished through the dissemination of good practices and incorporation of appropriate new genetic material (IFAD 2013 .p ix). Approximately 100,000 beneficiaries will receive training in shade crop management, water management, and crop diversification, developing coffee production. A further 32,000 families are expected to increase their asset base by over 20% (IFAD 2013 .p xi).

Resilience

It is expected that 20,000 families will make investment decisions and adopt management practices that improve their resilience to climate change impacts (IFAD 2013 .p xi, viii). In addition, the project intends to incorporate diversified agricultural practices in over 25,000 ha, to increase resilience and reduce climate risk. The project intends to provide more robust climate information through improved dissemination as well (IFAD 2014 .p 25).

Mitigation

The project offers strong mitigation benefits per unit area of land, and is expected to mitigate 2 million tonnes of CO_2e or more (IFAD 2015).

Other co-benefits

The project is expected to reduce the prevalence of childhood malnutrition within beneficiary families by 10% (IFAD 2013 .p xi). In addition, 200,000 people will indirectly benefit through increased labour demand and public infrastructure improvement (e.g. roads) (IFAD 2013 .p viii).

Economic costs and benefits

Total financing for the NICADAPTA project is USD 37 million (IFAD 2013 .p 24). The project is expected to generate a 28% Economic Rate of Return, with a Net Present Value of USD 127.3 million (IFAD 2013 .p xi).

Barriers to adoption

One of the executing agencies, MEFCCA (Ministry of Family, Community, Cooperative and Associative Economy), is a fairly new ministry, which may result in a dearth of administrative capacity and efficiency (IFAD 2013 .p xii). In order to mitigate this risk, a Plan for Institutional Strengthening will be implemented with supervision from IFAD, based on the accumulated experience from the IFAD portfolio in Nicaragua (IFAD 2013 .p xii). There is also a risk that communities and beneficiary organizations will lack the necessary internal coherence and coordination to effectively administer the Investment Plans (IFAD 2013 p. xii). This shortcoming will be addressed through capacity building and follow-up investigations of the Investment Plans (IFAD 2013 p. xii). Finally, there may be a lack of good-quality genetic material needed to increment and renovate the area of cocoa and coffee plantations (IFAD 2013 p. xii).

Key success factors

Providing services which can strengthen both producers and public institutions will provide a foundation for the project's success. This will include the production and spread of climate-resilient technologies and agro-climatic information, emphasizing disease control (IFAD 2014 p. 25). Policy dialogue between the Government of Nicaragua and cooperation agencies will be encouraged to promote coffee production, while brokering private investments (IFAD 2014 p. 25). Strengthening MEFCCA's project and knowledge management, monitoring and evaluation will also be important, to ensure an effective and efficient implementation (IFAD 2014 p. 25).

Gender and social inequality

The project intends to target smallholder coffee and cocoa farmers based on their vulnerability to climate change, having a focus on women, indigenous, and other vulnerable populations (IFAD 2013 p. x). Many Nicaraguan women have already stepped up to take on a leading role in rural areas as a result of the armed conflicts in the 1980s, increasing their participation in decision-making on the farm (IFAD 2013 p. ix). The Project intends to strengthen this development by providing young women with assets and knowledge to develop rural businesses (IFAD 2013 p. ix).

Appendix II: Sources for case study selection

#	CCAFS portfolio sources considered	Description
1	CCAFS Planning and Reporting (P&R) Platform	Technical reporting platform of program participants.
2	Email request to CCAFS Flagship Leaders and Regional Program Leaders	Invitation to submit CSA initial list of examples and cases, demonstrating discernible and quantified costs/benefits.
3	CCAFS technical reports from program participants	Multi-year of submissions from all program participants, detailing ongoing activities.
4	CCAFS Core Team Commissioned Reviews, evaluations and impact assessments	Includes several theme and topic reviews, as well as outcome/success cases.

#	Other sources considered	Description
1	CGIAR Centre annual reporting	Latest year submissions for all CGIAR centres.
2	Search of published literature	Published literature to complete regional and sectoral coverage.

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