Large-scale implementation of adaptation and mitigation actions in agriculture

Working Paper No. 50

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

Peter J.M. Cooper, Sidsel Cappiello, Sonja J. Vermeulen, Bruce M. Campbell, Robert Zougmoré and James Kinyangi

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RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

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Correct citation:
Cooper, P. J.M., S. Cappiello, S. J. Vermeulen, B. M. Campbell, R. Zougmoré and J. Kinyangi. 2013. Large-scale implementation of adaptation and mitigation actions in agriculture. CCAFS Working Paper no. 50. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

This document is published by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is a strategic partnership of the CGIAR and the Earth System Science Partnership (ESSP). CCAFS is supported by the CGIAR Fund, the Danish International Development Agency (DANIDA), the Australian Government Overseas Aid Program (AusAid), Irish Aid, Environment Canada, Ministry of Foreign Affairs for the Netherlands, Swiss Agency for Development and Cooperation (SDC), Instituto de Investigação Científica Tropical (IICT), UK Aid, and the European Union (EU). The Program is carried out with technical support from the International Fund for Agricultural Development (IFAD).

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Photos:

Abstract

This paper identifies sixteen cases of large-scale actions in the agriculture and forestry sectors that have adaptation and/or mitigation outcomes, and distils lessons from the cases. The cases cover policy and strategy development (including where climate-smart objectives were not the initial aim), climate risk management through insurance, weather information services and social protection, and agricultural initiatives that have a strong link to climate change adaptation and mitigation.

Key lessons learned include:

- Trade-offs can be avoided, at least in the near-term and over limited spatial scale
- We need cost-effective and comparable indices for measuring GHG fluxes and for monitoring adaptive capacity
- Strong government support is crucial to enable large-scale successes
- Upfront costs may be substantial and can be met from multiple sources
- An iterative and participatory learning approach with investment in capacity strengthening is critical.

Keywords

Climate change, climate-smart agriculture, public policy, scaling up, adoption, implementation, impact, metrics

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Acknowledgements

The authors gratefully acknowledge the input of Mr Kolli N. Rao, Ms Osana Bonilla-Findji, Zoe Sinclair, Catherine Zanev, Farming First and two anonymous reviewers for their very helpful suggestions.

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is supported by the Canadian International Development Agency (CIDA), the Danish International Development Agency (DANIDA), the Swiss Agency for Development and Cooperation (SDC), UK Aid, Instituto de Investigação Científica Tropical (IICT), AusAID, Irish Aid, the Ministry of Foreign Affairs of the Netherlands, the European Union (EU), with technical support from the International Fund for Agricultural Development (IFAD).

Contents

1. Introduction

1.1. Purpose of this paper

With food security under threat from climate change, the agricultural sector provides compelling opportunities to adapt proactively to maintain food production and secure farmers' livelihoods, while also reducing greenhouse gas emissions. Double or triple wins for food security, adaptation and mitigation will always be an elusive goal; in reality trade-offs will need to be navigated. Perhaps an even greater challenge is bringing success to scale, so that agriculture contributes meaningfully to global targets for reductions in greenhouse gas (GHG) emissions, while also providing equitably for the dietary needs of growing human populations. While many pilot projects exist, it is critical to know whether interventions that address climate challenges in agriculture can be brought to scale. The purpose of this paper therefore is to examine, through case studies, the evidence emerging from existing large-scale initiatives in agriculture that address both mitigation and adaptation agendas in the context of food security. The paper seeks to inform future interventions in agriculture by identifying factors that appear important for success as well as the challenges that have been faced.

In this paper, as a short hand for agricultural adaptation and/or mitigation, we use the term Climate-Smart Agriculture (CSA). CSA is a term that has been widely and sometimes obliquely used in spite of having a clear definition (FAO, 2010, DFID, 2012. See Box 1).

1.2. Climate, agriculture and adapting to climate change

Humankind has long recognized the impact that the prevailing weather conditions have on agricultural production and over the centuries the natural sciences have determined the principles that govern how climate effects agricultural production. It is largely because of such understanding that enormous gains in productivity have been possible, enabling the world to continue feeding an ever expanding human and animal population. Recognizing that gains in food production will have to be maintained in the future, but that this needs to be done in an environmentally benign manner, the concept of ‘sustainable agriculture’ has become fundamental to development parlance and practice (FAO 1995).

However, it is now accepted that the emissions of GHGs resulting from many sectors of human activity are causing the world to warm at an unprecedented rate which in turn will inevitably have long-term effects on rainfall amounts and distribution patterns, and on sea level rise (IPCC, 2007). Not only must agricultural development aspire to the goal of being sustainable, but it must now aspire to being sustainable in the context of a progressively changing climate. Farming practices will need to adapt over time to those progressive changes.

In adapting agriculture to climate change, a ‘two-pronged’ approach is required (Washington *et al*. 2006; Cooper *et al*. 2008). This two-pronged approach, sometimes referred to as the ‘twin pillars’ of adaptation (Cooper and Coe, 2011), is especially important for resource-poor farmers in the developing world who are currently most vulnerable to the climate-induced risks and shocks imposed by today’s climates. Firstly in the shorter term, it is essential to help farmers to build their livelihood resilience and adaptive capacity by enabling them to cope better with current climate-induced risk as a pre-requisite to adapting to future climate change. Secondly, in the medium to longer term and as climate change becomes more obvious, both in its identification and impact, farmers will have to progressively adapt their practices to a new and evolving set of climate-induced risks and opportunities. Rickards and Howden (2012) describe how such progressive adaptation is likely to evolve from ‘Incremental adaptation’, through ‘Systems adaptation’ to ‘Transformational adaptation’ as the degree of climate change becomes progressively more pronounced.

1.3. Agriculture and greenhouse gas (GHG) emissions

Up until the relatively recent time that scientists came to understand the role that GHGs played in global warming, the climate-agriculture interaction was largely viewed as a ‘one way street’, in other words, climate impacted on agriculture production. Now we recognize that it is more than that. It is a two way street. Agriculture also contributes to climate change through the emission of GHGs and hence to global warming and climate change.

Table 1. Estimated non-CO_2 emissions from within agriculture ($GtCO_2e$). (US-EPA, 2011).

Source	Year 1990	2005	2030
N2O - soil	1.80	1.98	2.67
CH4- enteric fermentation	1.76	1.87	2.29
N2O and CH4 - manure	0.41	0.39	0.46
CH4 - rice	0.67	0.71	0.74
N2O and CH4 - other (1)	1.28	1.16	1.16
Global total	5.92	6.11	7.31

(1). Burning of savannah, burning of agricultural residues, burning during forest clearance and emission from agricultural soils

GHG emissions from within agriculture are estimated to account for between 10-12% of the global total anthropogenic emissions, or around 6.1 $GtCO_2e$ per annum (1Gt = 109 tonnes). Of the GHGs emitted by agriculture, the non-CO_2 gases, notably nitrous oxide (N2O) and methane (CH4), are by far the most important with the agricultural sector accounting for 84% of the global N2O emissions and 54% of the global CH4 emissions (Verchot, 2007). Emissions of these two GHGs have increased 3% between 1990 and 2005 and by 2030 they are projected to be 24% higher than in 1990 (Table 1).

Adopting a more holistic approach, Vermeulen *et al*. (2012) considered GHG emissions from the food system as a whole which includes pre-production activities, agricultural production activities (+ land cover change as a result of agriculture) and post-production activities. They estimated that food systems contribute 19-29% of global anthropogenic GHG emissions, releasing 9.8–16.9 $GtCO_2e$ in 2008. Agricultural production, including indirect emissions associated with land-cover change, contributes 80%–86% of total food system emissions, with significant regional variation.

However, agriculture also has considerable potential to mitigate climate change through sequestering GHGs. For example, Smith *et al*. (2008) estimated the global technical mitigation potential3 within agriculture (excluding associated land use change) as between 5.5 and 6.0 $GtCO_2e$ per annum with the greatest technical potential for climate change mitigation

3 The gap between technical potential and realized GHG mitigation occurs due to barriers to implementation, including climate and non-climate policy, and institutional, social, educational and economic constraints (Smith *et al*. 2008).

lying in increasing soil carbon. Whilst, Powlson *et al*. (2011) caution against overestimating the potential for soil carbon sequestration to mitigate climate change, mitigation through the reduction of N2O and CH4 emissions offer a much smaller opportunity. However, these estimates of the 'technical potential' assume no policy, institutional, or economic barriers. When such factors are taken into account the 'realizable' potential will inevitably become much lower.

It is now recognized, therefore, that the goal of development through sustainable agriculture must more explicitly acknowledge and integrate, not only the emerging need for agricultural systems to adapt to progressively changing climates, but must also consider the fact that agriculture itself can contribute to or help mitigate the process of climate change. As a result, the concept of Climate-Smart Agriculture has emerged (see Box 1). Although different in wording, these two definitions have a great deal in common in that (i) they both incorporate the key elements of the definition of sustainable agriculture, (ii) that farming systems will need to adapt to climate change, and (iii) that agriculture both emits and sequesters GHGs.

Box 1. Climate-Smart Agriculture (CSA)

FAO (2010) CSA is 'agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals.

DFID (2012) CSA helps: (i) Support the livelihoods of smallholder farmers and build prosperity, (ii) Produce the food farmers and consumers need, (iii) Improve people's nutrition – especially that of women and children, (iv) Help farmers adapt to existing and future climate risks, (v) Sustain the health of the land and increase its productivity, (vi) Avoid the loss of forests and biodiversity, (vii) Store carbon in the soil and reduce emissions of greenhouse-gas from agriculture.

1.4. Choosing criteria to select the CSA case studies.

We used the following criteria to select the case studies:

- Implementation had to be large-scale, i.e. covering tens of thousands of farmers or tens of thousands of hectares;
- Innovative policies, already in place, specifically designed to enable the wide scale adoption of CSA were also considered even if the above criterion was yet to be attained;
- The case studies could come from the agriculture, livestock, forestry, and fisheries sectors; from both rain-fed and irrigated agriculture, and could be on-farm practices only or at the landscape level;
- The case studies could come from both the developed and the developing world;
- Innovations chosen were ‘climate change related’ through either one or a combination of the following; (i) climate risk management/reduction, (ii) advanced preparation for future climates, (iii) carbon sequestration, and (iv) reduced GHG emission.

2. Case study summaries

We identified four broadly defined categories of initiatives (see Table 2) into which our sixteen selected case studies fell. Below we present summary background information for each case study and provide a key reference for each. The full case studies and literature accessed for each can be found online at: <http://hdl.handle.net/10568/24863>.

Table 2. Matrix of Case Studies

Category of large-scale initiative	Case studies
1. Policies & national strategies where CSA is the major aim	▪ Brazil: Low Carbon Agricultural Programme ▪ Australia: Carbon Farming Initiative ▪ Denmark: Agreement for Green Growth ▪ Kenya: Agricultural Carbon Project
2. Policies & national strategies where CSA is not a major aim but which have significant CSA side effects	▪ Niger: Community Action Plan ▪ Tanzania: Participatory Forest Management ▪ Morocco: Plan Maroc Vert
3. Climate risk management through insurance, weather information services, and social protection	▪ India: Weather-based Crop Insurance Scheme ▪ India: Integrated Agrometeorological Advisory Services ▪ Ethiopia: Productive Safety Net Programme
4. Agricultural initiatives that have a strong link to climate change adaptation and mitigation	▪ Vietnam: Sustainable Intensification in Rice Production ▪ Niger: Farmer Managed Natural Regeneration ▪ China: Grain for Green Programme & Loess Plateau ▪ Canada: Herbicide Tolerant Canola ▪ Africa: Drought Tolerant Maize for Africa ▪ West African Sahel: Contour Stone Bunds

2.1. Policies and national strategies where CSA is the major aim

Brazil: Low Carbon Agricultural Fund

In 2010, the Brazilian Government launched the Low-Carbon Agricultural Programme (Programa Agricultura de Baixo Carbono) with the specific objective of 'promoting the adoption of sustainable agricultural systems and practices that at the same time reduce GHG emissions, whilst improving the efficiency and resilience of rural communities and agricultural activities'. By offering farmers favorable lines of credits, the program seeks to encourage six activities, namely (i) No-till agriculture, (ii) Rehabilitation of degraded pastures, (iii) Integrated crop-livestock-forest systems, (iv) Planting of commercial forest, (v) Biological nitrogen fixation to reduce N-fertilizer use, and (vi) Animal waste treatment. The program has an overall goal of a reduction of more than 160 million tonnes CO_2e emissions annually by 2020. It has a total budget of R$ 3.15 billion (~US$ 1.5 billion). By its second year, 2011–12, the program had supported 2,144 projects with a total value of US$ 251 million.

Key reference: Angelo, (2012).

Australia: Carbon Farming Initiative

The Australian agricultural sector accounts for 18% of the total national GHG emissions. In December 2011, the Australian Government launched The Carbon Farming Initiative to help Australia achieve its GHG reduction obligation along with protecting and improving the environment and climate change resilience. The initiative gives farmers and landholders the opportunity to acquire Australian Carbon Credit Units by storing carbon or reducing GHG emissions on their land. There are two types of Credit Units: (i) Kyoto-consistent (credits for reforestation, avoided deforestation, and reducing emissions from manure, fertilizer, legacy waste and livestock) which can be sold to overseas buyers and (ii) Non-Kyoto-consistent (credits for soil carbon, feral animal management, improved forest management, and non-forest vegetation) which can only be used in the voluntary markets or in domestic Government programs. An eligible CFI offset project is required to be on the positive list; apply a government approved methodology determination; not be on the negative list; and not be legally required. Currently there are four 'methodology determinations' related to (i) permanent environmental planting of native species, (ii) reduction of GHG through early dry season savanna burning, (iii) destruction of methane generated from manure in piggeries, and (iv) capture and combustion of methane in landfill gas from legacy waste. By November 2012, one piggeries project, one savanna project and five landfill projects have been declared eligible.

Key reference: Macintosh and Waugh (2012).

Denmark: Agreement on Green Growth

In accordance with the 1997 Kyoto Protocol, Denmark has committed to a 21% reduction in GHG emissions between 1990 and 2012. The agricultural sector is the second largest contributor to Danish GHG emissions after the energy sector and accounts for about 24% of the total national GHG emissions. In 2009, Denmark launched the Agreement on Green Growth which seeks to reduce GHG emissions from the agricultural sector by 800,000 tonnes of CO_2e annually. The Agreement on Green Growth builds on several existing measures in Danish legislation which target the agricultural sector and which have already or will in the future reduce the sector's GHG emissions. They all shared the overall aim of reducing nitrogen losses from agriculture activity. Now added to these initiatives is the Riparian Zone Act which enforces buffer zones along all streams and lakes in rural areas that are free of cultivation, fertilization and pesticide use. Between 1990 and 2010, Danish agriculture has succeeded in combining growth with an overall 19.4% reduction in GHG emissions. Whilst these GHG gains have largely been due to reductions in nitrous oxide emissions, which have fallen by 31% between 1990 and 2007, a 5% reduction between 1990 and 2010 in methane emissions from enteric fermentation was also reported, largely due to reduced cattle numbers. **Key reference:** Rasmussen *et al*. (2009).

Kenya: Agricultural Carbon Project

In November 2010, this project, implemented by Vi Agroforestry, became the first soil carbon sequestration project in Africa to sign an Emissions Reduction Purchase Agreement with the World Bank's BioCarbon Fund. The project is located in Western Kenya, an area dominated by subsistence farming on highly degraded farmlands with an average farm size of less than 1 hectare. The project is piloting the 'Adoption of Sustainable Agricultural Land Management' (SALM) methodology under the Voluntary Carbon Standard. Farmers choose from a range of practices which include improved agronomic practices, agroforestry innovations, restoration and rehabilitation of degraded land, and improved livestock management. Project monitoring is through the Activity Baseline and Monitoring Survey (ABMS). A sample of farmers completes the survey every month and receives payment according the carbon gains that are estimated from these reports. The revenue from carbon credits is distributed between farmers groups, Vi Agroforestry extension operations, and Vi Agroforestry headquarters in Stockholm. The project aims to involve 60,000 households in 3,000 farmer groups, covering an area of approximately 45,000 ha. Projected reductions in GHG emissions are 1.2 million tonnes CO_2e over a period of 20 years. To date 15,000 farmers in 800 farmer groups have adopted the SALM methodology. The first payments to farmers are expected towards the end of 2012 once the ABMS are verified.

Key reference: Shames *et al*. (2012).

2.2. Policies and national strategies where CSA is not a major aim but which have significant CSA side effects.

Niger: Community Action Plan

In 2003, the first phase of Niger's Community Action Plan was launched to 'prime the pump of decentralization'. In addition to building schools, literacy centers, health posts and wells for drinking water, local governments also financed over 1000 income generating projects which benefited an estimated 100,000 people, 80% of whom were women. These micro-projects led to increased agricultural productivity, increased vegetative cover, increased carbon sequestration and reduced sedimentation of watercourses. Water and soil erosion were also reduced in 88% of the sites. In November 2010, Niger's 'Strategic Programme for Climate Resilience' was approved. It includes five investment projects, one of which is the Community Action Plan for Climate Resilience. The resilience plan is aligned with and will strengthen the activities of the second phase of the Community Action Plan and will be implemented between 2012 and 2017 with an overall aim of 'Improving the resilience of the populations and of production systems to climate change and variability, in order to increase national food security' and a budget of US$ 63 million.

Key reference: CIF (2012).

Tanzania: Participatory Forest Management

Since the late 1990s, the government of Tanzania has pursued forest reform policies that promote community participation in forest management as a way to protect natural forests against degradation and enhance the benefits derived from participatory forest management (PFM) for farming communities living within the margins of forests. From a CSA perspective, success in PFM is important in reducing deforestation and forest degradation since agricultural expansion is the major driver of forest cover loss. In addition, PFM enables the diversification of livelihood strategies of participating agricultural communities, hence building adaptive capacity. Through its Forest Policy of 1998 and the Forest Act of 2002, the government provided a legal basis for communities to own and manage forest resources on village lands and within government forest reserves. By 2008, there were 1,800 villages with over 7,000 participating households across 60 or more districts, providing for the rehabilitation and preservation of nearly 4.0 million hectares of forests in Tanzania. Agreements between the district councils and the local village councils allow for co-management and a benefit sharing mechanisms where the villages retain a portion of the monies from fees, licenses and permits paid in respect of the local bye-laws. Between 2011 and 2016, Tanzania plans to invest nearly 40 million dollars in commercialization and enhancing the productivity of forests.

Key reference: Pfliegner (2010).

Morocco: Plan Maroc Vert

Agriculture in Morocco accounts for 16% of the GDP and is the principal source of income for 43% of the population. With 80% of its territory being arid to semi-arid, agriculture is prone to large season-to-season variability in production. Designed to usher in a substantial shift away from a highly protected market to a more open market-oriented agriculture, in 2008 the Government launched the Moroccan Green Plan (Plan Maroc Vert) with a planned investment of US$ 17 billion by 2020. The plan lays out a series of public sector reforms aiming to transform the agricultural sector into the driving force for broad-based economic and social growth in rural areas. It seeks to create one million new agricultural jobs and to improve the incomes of three million rural poor by 2-3 fold. The plan is built on two pillars: Pillar 1 promotes a modern and competitive agriculture adapted to markets and Pillar 2 is dedicated to combating rural poverty through increasing the agricultural revenues of the most vulnerable farmers in marginal areas. By 2011, 64 projects within the food production sector covering 132,000 hectares with an investment of US$ 2 billion, and 108 projects which address high added value agriculture across 336,000 hectares with an investment of US$ 570 million have been launched. Compared with the period 2005-2007, production has increase by 190% in the olive sector, by 20% for citrus production, 52% for cereals, 45% for dates and 48% for red meat. In 2011 and co-financed through GEF, the Moroccan Government launched the project 'Integrating Climate Change into the Plan Maroc Vert'. Ex ante analyses project that this will result in carbon gains of 63.5 million tonnes CO_2e over 20 years, largely from the sequestration of soil carbon from improved agronomic practices.

Key reference: Saoud (2011).

2.3. Climate risk management through insurance, weather information services and social protection.

India: Weather Based Crop Insurance Scheme

As an alternative to the existing Area-Yield based National Agricultural Insurance Scheme, the Weather Based Crop Insurance Scheme was launched as a pilot in 2007 with the objective of 'mitigating the hardship of the insured farmers against the possibility of financial loss associated with low crop yields or crop failure resulting from adverse weather conditions.' The scheme is a publicly subsidized index-based insurance scheme. By the 2010-11 agricultural year over 9 million Indian farmers held scheme policies with premium volume of over US$ 258 million and total sum insured over US$ 3.17 billion. The volume of paid claims in 2011 amounted to US$ 125 million. These policies covered over 40 different crops and 9.5 million hectares. In the 2011-12 agricultural year, over 11.6 million farmers held the policies covering a risk valued at US$ 4.18 billion with a premium volume of US$ 370 million.
Key reference: Rao (2011).

India: Integrated Agrometeorological Advisory Services

These services were launched in 2007 with the objective of 'generating agro-meteorological information while developing suitable dissemination systems to improve crop and livestock productivity'. It is a multi-institutional project which involves stakeholders from agricultural universities, research units, NGO's, and media agencies. It generates four products, namely (i) a meteorological component consisting of weather observation and forecasting for the next 5 days, (ii) an agricultural component, which identifies 'weather sensitive stresses' and converts weather forecasts into appropriate farm-level advisories, (iii) an extension component with two-way communication between farmers and agricultural scientists, and (iv) an information dissemination component employing mass media. The bulletins are issued at three institutional levels, National, State, and District. The latter targets farmers and is provided by

Agromet Field Units located within State Agricultural Universities. Currently the project provides services to over 2.5 million farmers. To date, the program has had an estimated economic impact of more than US$ 10 billion.

Key reference: IMD.NA.

Ethiopia: Productive Safety Net Programme

The Ethiopian Government launched the multi-donor program in 2005 with the objective of 'providing transfers to the chronically food insecure population in a way that prevents asset depletion at household level and creates productive assets at community level', thus replacing continual appeals for emergency food aid with a more predictable safety net. In the program beneficiaries receive both cash and food support. The transfers are distributed to both direct and indirect support beneficiaries. The direct support beneficiaries (84% in 2008) are required to attend temporary employment in 'public workfare projects', whilst the indirect support beneficiaries who are unable to contribute to public works due to labor constraints are not required to work. The 'public workfare projects' include, for example, the establishment of area enclosures, woodlots, construction of hillside terraces, shallow wells and ponds, and stream diversion for irrigation. A household 'graduates' from the program when it is deemed to have become 'food sufficient.' The program has been implemented in 7 out of 10 regions in Ethiopia and has reached about 8 million people. By 2010, 70% of program households perceived their overall economic condition as better or the same compared to the previous year, and between 2004 and 2010, the level of assets had increased and distress sales had declined, regardless of beneficiary type. The program has also had a range of positive, practical impacts on women and their families.

Key Reference: World Bank (2011).

2.4. Agricultural initiatives that have a strong link to climate change adaptation and mitigation

Vietnam: Sustainable Intensification in Rice Production

This system increases the productivity of rice by changing the management of plants, soil, water and nutrients through optimizing the performance of the individual rice plants rather than relying on maximizing inputs. The system offers two important climate related benefits, namely (i) reduced demand for water through intermittent draining of the paddy fields and (ii) reduced methane gas emissions through paddy soils being intermittently dried and thus mostly aerobic. The system was officially launched in Vietnam by the Ministry of Agriculture and Rural Development in 2007 with the objective of 'further expanding the Sustainable Intensification in Rice Production of Vietnamese small-holder farmers through community-led agricultural development, while managing soil and water resources more efficiently and sustainably'. By 2011, over 1 million farmers (about 10% of all rice growers in Vietnam) were using the approach on 185,000 ha across 22 provinces. Compared with conventional practice, yields have increased by 9-15% and inputs have been reduced: 70–75% less seed, 20–25% less nitrogen fertilizer, and 33% less water resulting in an estimated extra income of US$ 95-260/ha/crop season. Changes in methane and nitrous oxide emissions have not been quantified in Vietnam.

Key reference: SIR RICE (2012).

Niger: Farmer Managed Natural Regeneration

Niger's farmers have long practiced woodland management by selecting, protecting and pruning re-growth from living tree rootstock, an approach that became known as 'Farmer Managed Natural Regeneration'. In the mid-1980's this system became a component of a successful 'Maradi Integrated Development Project'. Since that time, local, national and internationals partners have continued to collaborate in facilitating the scaling up of the practice. By 2008, an estimated five million hectares of land has been transformed with approximately 200 million new trees, affecting around 2.5 million people and especially benefiting women. It has been estimated that the aggregated value of the practice, resulting from improved soil fertility, fodder, food, firewood and others, as a minimum of US$ 56/ha/year. Although not quantified, it is likely that the practice has had significant climate change implications through the large-scale sequestration of atmospheric carbon by the 200 million new trees. Advocacy and a change in policy were important. The spread of the practice was stimulated after the Nigerien Government eased restrictive national forestry regulations thus allowing the farmers 'rights' to the trees that they protected, rights that had hitherto belonged to the Government.

Key reference: Haglund *et al*. (2011).

China: Grain for Green Programme

This program, launched in 1999 in response to devastating floods, has the objective of 'reducing erosion by restoring forest and grasslands on low-yielding sloping cropland and secondly to help alleviate poverty'. It has a total budget of US$ 40 billion. It is China's first payment scheme for ecosystem services and is based on a cropland set-aside program. The program targets lands with 15 degrees of slope or more with three types of land use conversion – cropland to forest, cropland to grassland, and wasteland to forest. Participating households are compensated according to the amount of farmland they set aside with in-kind grains provision, cash payments, and free seedlings. The Loess Plateau was identified as a priority region for the program and covers a total area of 624,000 km2 of which over 60% faced severe erosion. Between 2000 and 2008, the area of land use conversion has already amounted to 2 million ha and has benefitted 2.5 million households. It is estimated that in the Loess Plateau, the program has had significant positive impacts on carbon sequestration, with increased carbon levels in soils and rehabilitated vegetation found to be 11.54 and 23.76 megatonnes carbon, respectively.

Key reference: World Bank (2007).

Canada: Herbicide Tolerant Canola cropping

Genetically modified crops have substantial potential to reduce agriculture's contribution to global GHG emissions due to less fuel used in cultivation and herbicide application as well as increased soil carbon sequestration under reduced till systems. In Canada, unrestricted commercial production of Herbicide-tolerant canola (*Brassica napus*) began in 1997. Since its introduction, the adoption of Herbicide-tolerant canola has been rapid, rising from 26% of the total canola area in 1997 to 78% by 2002 and 95% by 2007 corresponding to an area of 6 million ha. From 2005-7, the direct and indirect benefits from this technology generated an annual additional CAD$ 1.063-1.192 billion resulting from lower input costs and higher yields due to improved weed control. Herbicide application has been reduced by 1.3 million kg active ingredients annually and nearly two thirds of these canola producers are using either zero-tillage or minimum tillage as the preferred form of weed management. Soil organic carbon levels have increased resulting in improved water retention capacity. It estimated that 1 million tonnes of carbon is either sequestered or no longer released under land management facilitated by this canola production, as compared to 1995.

Key reference: Beckie *et al*. (2011).

Africa: Drought Tolerant Maize for Africa Project

For over 300 million people in sub-Saharan Africa, maize (*Zea mays*) is a vital staple food crop with the vast majority being grown under rain-fed conditions. Drought tolerant varieties are therefore a crucial component in the battle against climate-induced crop failure and food insecurity in Africa. In response to the prevalence of current droughts and the projected increase in their frequency, this project was launched in 2006, coordinated by the International Maize and Wheat Improvement Center and the International Institute of Tropical Agriculture (CIMMYT NA). The Drought Tolerant Maize for Africa Project (DTMA) is comprised of a broad partnership between national agencies, non-governmental organizations, seed companies, certification agencies and farmer groups in 13 countries. The project aims to develop and disseminate drought tolerant, high-yielding, locally-adapted maize. To date more than 34 new drought tolerant maize varieties have been developed and deployed to approximately 2 million smallholders across 13 African countries. An ex-ante assessment study on the potential impacts of the project suggests that (with optimistic adoption rates and yield increase of 10-34% over non-drought tolerant varieties) the project could lead to a cumulative economic benefit of nearly US$ 0.9 billion to farmers and consumers.

Key reference: CIMMYT & IITA (2007).

West African Sahel: Contour Stone Bunds

High intensity rainfall coupled with low fertility and crust-prone soils are characteristic of the Sahel and result in widespread rainfall runoff and soil erosion, hence priority has been given to a range of measures for runoff and soil erosion control. One such measure, the construction of stone bunds on natural contour lines, has been promoted for more than 25 years and has proven to be both an effective and durable innovation. Between 200,000 and 300,000 hectares of degraded land has been rehabilitated in the Sahel through their use. However, since they are costly and labor intensive to construct, they are seldom adopted without substantial financial and institutional support. Best results are achieved when contour stone bunds are used in combination with biological measures such as the additional planting of grass on the contour lines and the complimentary use of mulch or fertilizer is often required for associated improvements in crop yields. Where soils are particularly degraded and liable to run-off, farmers often combine contour stone bunds with traditional ‘zai’ planting pits. Contour stone bunds are important in the context of CSA and are likely to prove beneficial under both wetter and drier climate change scenarios. In wetter years they protect the soil against excessive erosion and in drier years they still contribute to effective rainwater harvesting. In addition, since heavy rainfall events in the Sahel are projected to increase in frequency and intensity with global warming, durable and effective soil erosion control structures constitute an important adaptation strategy.

Key reference: Landolt (2011).

3. Going to scale with CSA: lessons learned

3.1. Trade-offs can be avoided, at least in the near-term and over limited spatial scale

FAO (2010) defines CSA as 'agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals. Thus, by definition and in a perfect world, in going to scale with CSA there should be not be any trade-offs among (a) better management of current climate-induced risks, (b) progressive adaptation to climate change, (c) mitigation of climate change, (d) current food security, and (e) current development priorities. While trade-offs cannot be entirely avoided and need to be understood, the case studies here demonstrate that current, known trade-offs can be navigated successfully at national and sub-national levels. At the same time, globally, there will inevitably have to be some trade-offs between the two imperatives of achieving food security for a rapidly expanding human population and mitigating climate change.

For policies and strategies in which CSA is the major aim, the four initiatives reviewed are still too recent to have had documented impact, but they have been specifically designed to integrate mitigation of climate change with improved resilience of production systems and peoples' livelihoods, leading to positive impacts for food security at local and national levels. The objective of initiatives on 'Climate risk management through insurance, weather information services and social protection' is specifically to help farming households cope better with current climate-induced production risk. Our case studies suggest that in all three instances that objective was being met. However, these climate risk management initiatives are designed to address the climate related risk that people face today. What is not yet clear is the extent to which these initiatives have led or will lead to the future long-term livelihood resilience and enhanced adaptive capacity of rural communities.

It is in the category of 'Agricultural initiatives that have a strong link to climate change adaptation and mitigation' that we find the most positive lesson. These initiatives are designed, in one way or another, to address poverty, food insecurity, or environmental degradation. As noted earlier, there is always the danger that there may be trade-offs between solving today's problems and addressing the challenge of adapting to or mitigating future climate change. An example of this latter situation would be the case of fertilizer subsidies in Africa. For example, Denning *et al*. (2009) describe the immediate large-scale and beneficial effects of fertilizer subsidies in Malawi. While it is questionable how sustainable such subsidies can be and hence to what extent they can enhance people's livelihood resilience in the longer term, the immediate impact on food security and poverty alleviation has been very positive. It has provided 'breathing space'. However, this has to be traded off against the negative aspect of almost certain increases in nitrous oxide emissions due to more widespread N-fertilizer use. In contrast, our case studies provided encouraging evidence that initiatives specifically designed to address poverty, food insecurity and environmental degradation also have potentially substantial mitigation benefits (however see next section), which can provide a direct source of income to farmers and land managers, and longer-term benefits to reliability of food production. For policy makers in developing countries who have to address food shortages, extreme levels of poverty and very often a degrading natural resource base on a day-to-day basis, this perhaps is an encouraging lesson.

Overall, while trade-offs may be avoided in the present, we are less aware of and less able to control trade-offs in the future. The same issue pertains to spatial scale: while there may not be trade-offs locally, there is potential for 'leakage'. For example, reduced emissions in Danish pig farming associated with reduced production may simply displace the emissions to another country, if demand remains the same. Indirect impacts, leakage and displacement effects are a constant challenge for both mandatory and voluntary sustainability initiatives, and it is difficult to establish clear, fair, effective mechanisms to deal with these trade-offs. The Australian Carbon Farming Initiative requires each registered project to demonstrate how it will address leakage. It will be instructive to follow this program in future to learn how this explicit effort to internalize, and take responsibility for, indirect effects will fare in practice over time.

3.2. We need cost-effective and comparable indices for measuring GHG fluxes and adaptive capacity

Our case studies suggest that there is a severe lack of on-the-ground measurement of GHG emissions and sequestration. The literature we accessed often provides estimates of what might have occurred or describes the potential GHG gains that the innovation offers, but these are seldom backed by in situ evidence. This is important since, as noted by Smith *et al*. (2007), estimates of the 'technical potential' assume no economic or institutional barriers. 'Realizable potentials' will inevitably be lower. Thus without such on-the-ground measurement, it is very difficult to say with certainty which kinds of technologies and approaches are the most promising or indeed what the impact has been.

Similarly, in the case studies, the result of enhanced adaptive capacity from initiatives is not measured, but rather assumed based on first principles – for example that trees provide additional income, fodder and crop yield, which in turn translates into raised adaptive capacity. There is little hard evidence of such improved adaptive capacity. However, there are challenges in measuring and monitoring 'improved adaptive capacity', a key component of climate-smart agriculture. As noted by Vincent (2007), there are pertinent and critical issues of uncertainty in determining adaptive capacity at different levels, from household to country. Many key variables cannot be quantified (Yohe and Tol, 2002).

As agricultural discussions within the Subsidiary Body for Scientific and Technological Advice (SBSTA) advance in the future, we would hope to see both the aspects of adaptation to and the mitigation of climate change included, and one of the first tasks of the work program could be the development of realistic protocols for the measurement of (a) GHG emissions and sequestration, and (b) adaptive capacity. This is especially the case in the smallholder sector where usually a wide range of agricultural enterprises exist at the farm and landscape level. A smallholder protocol would need to encompass a systems analysis of whole farms and landscapes to identify options that are most likely to also benefit farmers' livelihoods, food security and adaptive capacity. Such a protocol would also address specifications for sampling and measurement of GHG emissions and carbon sequestration.

3.3. Strong government support is crucial for large-scale success

Strong leadership and support from Governments was essential for successful scaling up in all but one of the case studies. Appropriate support may entail changes in legislation, government-administered programs, provision of finance and incentives, or partnership among multiple agencies (Table 3). Even in the case of the 'bottom-up' initiative of Farmer

Managed Tree Regeneration in Niger, it is doubtful that success would have been achieved on the scale it has been without the Nigerien government relaxing existing tree tenure laws.

In almost all instances government support was invaluable in elaborating approaches and frameworks for scaling up initiatives in their countries. This would seem essential to future initiatives, since the implementation of large-scale programs, particularly those that target millions of small-scale farmers will always be complex and require the participation of a wide range of institutions at different levels in each country. The Productive Safety Net Programme in Ethiopia and the Grain for Green Programme in China are good examples of this. Clearly it will be governments themselves that best know the roles and competencies of all the institutions in their countries that need to be involved and that can best elaborate frameworks in which all partners can effectively fulfill those roles.

Table 3. Major types of Government support for large-scale initiatives.

Initiative	Political support	Funding	Scaling up approach
Brazil: Low Carbon Agricultural Fund	Government program	x	x
Australia: Carbon Farming Programme	Government program	x	x
Denmark: Green Growth Plan for agriculture	Government program	-	x
Kenya: Agricultural Carbon Project	-	-	-
Niger: Community Action Plan	Government program	-	x
Tanzania: Participatory Forest Management	Government program	x	x
Morocco: Maroc Plan Vert	Government program	x	x
India: Weather-based Crop Insurance Scheme	Government policy, implemented by private sector	x	x
India: Integrated Agromet. Advisory Services	Government program	x	x
Ethiopia: Productive Safety Net Programme	Government program	-	x
Vietnam: System of Rice Intensification	Government collaboration with other partners	x	x
Niger: Farmer Managed Tree Regeneration	Government program and change in implementation of law	-	x
China: Grain for Green Programme	Government program	x	x
Canada: Herbicide-tolerant Canola cropping	Government policy	-	-
Africa: Drought tolerant maize	Government approval for variety release	-	x
West Africa Sahel: Contour Stone Bunds.	Government collaboration with other partners	x	x

3.4. Upfront costs may be substantial and can be met from multiple sources

Most case studies have entailed high levels of upfront finance. The Brazil fund, for example, needed seeding of R$ 3.15 billion (~US$ 1.5 billion), while the Chinese government has spent RMB 191.8 billion (~US$ 28.8 billion) on the Grain for Green Programme over ten years, and the total budget is estimated at RMB 337 billion (over US$ 40 billion). High start-up costs are inevitable in such large-scale initiatives, even if the program is designed to be financially and economically sustainable and self-supporting in the longer-term. Costs are especially high in cases where they are targeted towards millions of small-scale and impoverished farmers who are unable to bear the brunt of implementation costs themselves however beneficial the outcomes may be. In the case studies, upfront costs related to the following: establishment of new institutions; provision of financial incentives to change behaviors; provision of social safety nets; subsidies to risk management; communications, extension and information-sharing; research and technology development; provision of services and any associated infrastructure (e.g. climate information services linked to weather stations and communications technologies); monitoring and evaluation.

In some countries costs were met from government sources (Table 3), but elsewhere initiatives were funded through collaboration with one or more donors (e.g. the Niger Community Action Plan, the construction of contour stone bunds in the Sahel and the Ethiopia Productive Safety Net Programme). Certain schemes, notably Herbicide-tolerant Canola in Canada, have had low upfront costs, which have been met by the private sector. An important lesson here is that finance to start up such programs is more likely to come from national government revenues, official development assistance, and the private sector than from dedicated international climate funds under the United Nations Framework Convention on Climate Change (UNFCCC). While there is commitment from developed countries to mobilize US$ 100 billion a year by 2020 to address the mitigation and adaptation needs of developing countries, in reality these funds are slow to materialize and insufficiently reliable. As these funds do begin to flow, perhaps two priorities for investment are transition funds to cover the upfront costs outlined above, and support to transactions costs, in order to lower the barriers for smallholder farmers to participate in adaptation and mitigation activities (Streck *et al*. 2012).

3.5. An iterative learning approach with investment in capacity strengthening is critical

The case studies that have been active over a number of years have in general made adjustments over time on the basis of lessons learned and changing circumstances. For example, the second phase of the Nigerien Community Action Plan has been able to build on the many positive and negative lessons of the first phase. Provision of opportunities for review and adjustment are likely to be features of any successful large-scale initiative. It is notable too that most of the case studies take an ‘innovation system’ approach rather than a ‘technology transfer’ approach. In other words, they include farmers and other beneficiaries as collaborators rather than recipients in the cycle of implementation and learning. The sustainable intensification of rice production in Vietnam, for instance, is founded on Farmer Field Schools in which farmers are able to experiment and share experiences with different agronomic practices. An important lesson here is captured in the words of the Kenyan Agricultural Carbon Project: ‘get the priorities right’. In other words, to succeed, these interventions generally need to put farmers’ concerns at the center – usually incomes, livelihoods and year-on-year stability – and design other aspects, particularly mitigation, around these concerns.

Almost all of the case studies involved a large number of partners; partners from different institutions and organizations within the specific countries involved, in many instances partnerships amongst the donor community supporting the initiative and in the case of Drought Tolerant Maize, partnerships that spanned across 13 African countries. The different skills and capacities of multiple partners in large-scale initiatives highlight the need for investment in capacity strengthening right across the board, not only with farmers. For example, in the Brazilian Programme, it became apparent that there was a limited awareness and understanding of the program goals and modus operandi among lending banks. In response, the largest lender to the program, the Bank of Brazil, has conducted training sessions for their branch managers which focus on the program (IPAM, 2012). In the case of PFM, the government of Tanzania has encouraged the participation of village institutions in decision making, thus building the adaptive capacity of local communities and enhancing the capacity of government institutions for action learning. In some other instances, a lack of people trained with the required skill set has been a partial obstacle. For example, in the case of crop insurance in India, the government has noted that “the task of appraising the diverse portfolio of weather insurances is very specialized and lies in the nexus of agriculture, statistics, meteorology, and financial risk management. Finding skilled personal is challenging” (Government of India, 2011).

4. Conclusion

In conclusion, the case studies selected demonstrate what is possible in agriculture and have enabled us to draw five key lessons that we believe are important, both for future interventions and future global negotiations. In summary, those lessons are:

1. Trade-offs between CSA aligned initiatives and current food security and development priorities can be avoided, at least in the near-term and over limited spatial scale.
2. Cost-effective and comparable indices for measuring GHG fluxes and adaptive capacity are needed in order to properly quantify the 'on the ground' benefits and impacts realized through CSA.
3. Strong government support is crucial for large-scale success, both from a policy perspective as well as in elaborating scaling up frameworks that most effectively utilize the comparative advantages of the local partners involved.
4. Upfront costs are usually substantial in such large initiatives, but can be met from multiple sources.
5. An iterative learning approach in large-scale initiatives with investment in capacity strengthening of the partners involved is critical.

5. Appendix

5.1. Low-Carbon Agricultural Programme, Brazil

Background information

In 2010, the Brazilian Government launched the Low-Carbon Agricultural Programme (Programa Agricultura de Baixo Carbono, ABC) with the aim of reducing GHG emissions from agriculture activities as well as to meet its pledge made at the 2009 United Nations Climate Change Conference in Copenhagen (Angelo, 2012). By offering farmers favorable lines of credits (5.5% annual interest rate and 5–15 years repayment period) the program seeks to promote the adoption of more sustainable and low-carbon agricultural practices (IPAM 2012). The ABC program specifically encourages a range of six activities with associated projections of CO_2e reductions in emissions by 2020 (CAN 2012; FAO 2012; FENATA 2012). These initiatives encompass the following enterprises:

1. No-till: Expanding the current area from 25-33 million ha will lead to an estimated reduction of 16-20 million tonnes of CO_2e.
2. Recovery of degraded pastures: The transformation of 15 million ha eroded lands into agriculturally productive areas will reduce emissions by 83-104 million tonnes of CO_2e.
3. Integrated crop-livestock-forest: An expected area increase of 4 million ha will prevent the emission of 18-22 million tonnes of CO_2e.
4. Planting of commercial forest: Planting 3 million ha of commercial trees (e.g. eucalyptus and pine) will result in an estimated reduction of 8-10 million tonnes of CO_2e.
5. Biological nitrogen fixation: An expected area increase of 5.5 million ha will lead to an estimated reduction of 8-10 million tonnes of CO_2e through reduced N-fertilizer use.
6. Animal waste treatment: The treatment of 4.4 million m^3 of waste from pig farming will reduce CO_2e emission by 6.9 million tonnes.

The ABC program is coordinated by The Ministry of Agriculture, Livestock and Food Supply (IPAM 2012) and has an overall goal of a reduction of more than 160 million tonnes CO_2e emissions annually by 2020 (Angelo 2012). The program is part of the Brazil's 2008 'National Plan on Climate Change' which targets a 36-39% reduction in Brazils' total GHG emissions by 2020 (IPAM 2012).

Objectives

The main objective of the ABC program is to promote the adoption of sustainable agricultural systems and practices that at the same time reduce GHG emissions, whilst improving the efficiency and resilience of rural communities and agricultural activities (CNA 2012). Additional objectives include assistance in accomplishing Brazil's 'Nationally Appropriate Mitigation Actions' presented at the 2009 United Nations Climate Change Conference, as well as supporting declining deforestation rates (FAO, 2012).

Funding

ABC is funded by the Brazilian Federal Government with a total budget of R$ 3.15 billion (~US$ 1.5 billion)

Early outcomes of ABC

The ABC program has had an initially slow adoption rate (Angelo 2012). According to IPAM (2012), only five projects received contracts with a value of U$1.7 million during the first year of implementation (2010–11). However, in the second year, 2011–12, the number of projects has risen to 2,144 with a total value of US$ 251 million. Given the very early stages of ABC, it is too soon to assess to what extent it is reaching its objectives and potential targets of reduced GHG emissions.

Lessons Learned

Three barriers have been identified which have, to date, hindered the rapid uptake of the ABC program (IPAM, 2012). Firstly, there is a lack of trained technical personnel amongst both banks and producers who are able to assess and validate projects. Secondly, there is a limited awareness and understanding of the program amongst banks. In response the largest ABC lender, the Bank of Brazil, has conducted training sessions for their branch managers which focus on the ABC program. Thirdly, farmers have complained about the bureaucracy of the ABC program. Indeed, according to Correio Braziliens (2012), the Brazilian Government has recognized that the bureaucracy involved in assessing credit coupled with unclear returns on investments are currently acting as a disincentive to many farmers in adopting the program.

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5.2. Australian Carbon Farming Initiative (CFI)

Sidsel F. Cappiello and Peter Cooper

Background Information

The Australian agricultural sector, including deforestation caused by agricultural activities, accounts for around 24% of the total national GHG emissions. However it also holds huge potential for reducing and offsetting GHG emissions (Sabto and Porteous 2011). Consequently, in December 2011, the Australian Government launched The Carbon Farming Initiative (CFI), a voluntary carbon credit offset certification scheme which aims to help Australia achieve its GHG reduction obligation along with protecting and improving the environment and climate change resilience (Macintosh and Waugh 2012).

The CFI framework is designed to work in combination with the carbon-pricing scheme under Australia's Clean Energy Act, implemented on 1st July 2012 (Oosterzee 2012). CFI gives farmers and landholders the opportunity to acquire Australian Carbon Credit Units (ACCU's) by storing carbon or reducing GHG emissions on their land. Because the program is voluntary, proponents do not incur a penalty if the emissions from the project exceed the baseline, other than the opportunity cost associated with lost credits. There are two types of ACCU's:

1. Kyoto-consistent (credits for reforestation, reduction in nitrous oxide emissions from fertilizer use, and managing methane emissions from livestock) which can be sold to overseas buyers.
2. Non-Kyoto-consistent (credits for soil carbon and improved forest management) which can only be used in the voluntary markets or in domestic Government programs (Oosterzee 2012).

The projects are furthermore separated into (i) sequestration offsets projects and (ii) emissions avoidance offsets projects (Carbon Credits (Carbon Farming Initiative) Act 2011).

Before an offsets project can start earning credits, it must first be declared eligible. An eligible CFI offset project is required to be on the positive list; apply a government approved methodology determination; not be on the negative list; and not be legally required (Carbon Credits (Carbon Farming Initiative) Act 2011). The positive list details all the activities that go beyond common practice and are therefore additional. The negative list includes activities which could adversely impact water, biodiversity, employment, communities, and agricultural production. These activities are excluded from the CFI. Currently there are four such methodology determinations which cover (i) Permanent Environmental Plantings of Native Species, (ii) Reduction of GHG through Early Dry Season Savanna Burning, (iii) Destruction of Methane Generated from Manure in Piggeries, and (iv) Capture and Combustion of Methane in Landfill Gas from Legacy Waste.

Beside the requirements of methodology determinations, an offset project must comply with 'integrity standards' including (i) projects must demonstrate 'additionality', documenting that reductions in GHG emissions are a direct result of project activities, (ii) abatement is measurable and verifiable, (iii) measurement methods use peer-reviewed science, (iv) that measurement is conservative, and (v) projects must account for 'leakage' or the "unanticipated increase in emissions outside a project's accounting boundary as a result of the projects implementation, for example, forest being cleared elsewhere as a result of a CFI project." In addition, sequestration projects also have a 'permanence' obligation of 100 years (Oosterzee 2012, p.239).

Objectives

The objectives of the CFI are threefold: (i) to assist Australia in achieving is obligations under the Climate Change Convention and the Kyoto Protocol, (ii) to create incentives for people to undertake projects which offsets GHG emissions, and (iii) the reductions in GHG emissions must be consistent with protecting Australia's environment as well as improving climate change resilience (Carbon Credits (Carbon Farming Initiative) Act 2011).

Funding

The Australian government has approved a broad range of measures to support the land sector and a number of research funds and skills programs will assist with the development of activities, methodologies, and projects (Department of Climate Change and Energy Efficiency (DCCEE), 2010). More than AUD$ 220 million is being spent on research and methodology development and almost AUD$ 100 million to directly support carbon farming activities on-farm. The government will direct revenue to the AUD$ 250 million Carbon Farming Initiative Non-Kyoto Carbon Fund to purchase CFI credits.

Early outcome and impacts

CFI has been in place since December 2011 and it is only recently that projects are being declared eligible.

The first piggeries project was declared eligible 12th October 2012: A pig farm in New South Wales is the first piggery in Australia to earn carbon credits. The farm has invested nearly $1 million on a biogas generator which both exports electricity to the grid and generates carbon revenues. The farm has 22,000 pigs and has gone from paying AUD$ 15,000 in monthly electricity bills to earnings of AUD$ 5,000. The carbon credits are expected to provide the farm about AUD$ 150,000 a year (Hannam 2012).

The first savanna burning project was declared eligible 2nd November 2012: The Indigenous Land Corporation has received approval to generate the credits on its 180,000 ha property located in the Northern Territory. In the past, uncontrolled fires had been burning approximately 70% of the property each year. By applying a method of controlled burning early in the dry season these fires have decreased to only 3% of the property area. The organization is expected to earn up to AUD$ 500,000 a year by using the CFI trading carbon scheme (AAP 2012).

Additionally, five landfill gas projects have been declared eligible under the CFI Act (CER 2012).

Lessons Learned

It is only recently that offsets project are being declared eligible. One of the reasons for the slow start was due to delays in the process of turning ‘methodologies’ into ‘determinations’ which took a longer time than anticipated (Gould, 2012). Such methodologies are central to project-based carbon transactions; however the cost of development of a new methodology is around US$ 125,000 and can take about two years from beginning to approval (World Bank, 2010).

CFI is likely to incur high transaction costs with the real cost of project development and implementation being so high that the return from the carbon payments may not be adequate to cover costs (Oosterzee, 2012). However, we note that the two case studies described above appear more positive than that. Oosterzee (2012) further argues that such high transaction costs will favor large landholders and discriminate against smallholders, the latter accounting for 86% of all agriculture and forestry businesses in Australia.

However, according to Macintosh and Waugh (2012), CFI has the capacity to reduce the cost associated with meeting Australia's mitigation targets whilst also promoting more sustainable land management practices. However, "the realization of this potential will rely heavily on how broadly regulation-making and administrative discretions are exercised and whether there are sufficient incentives for landholders to participate in the scheme."

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5.3. Agreement on Green Growth in Denmark

Background information

In accordance with the 1997 Kyoto Protocol Denmark has committed to a 21% reduction in GHG emissions between 1990 and 2012, and has put forward the ambitious goal of a society independent of fossil fuels by 2050 (KPR 2011).

The agricultural sector is the second largest contributor to Danish GHG emissions after the energy sector (Nielsen *et al*. 2012), and accounts for about 24% of the total national GHG emissions (Dalgaard *et al*. 2011). In 2009, Denmark launched the Agreement on Green Growth (AGG) which seeks to reduce GHG emissions from the agricultural sector by 800,000 tonnes of CO_2e annually as a result of several energy, nature, and environmental measures. Full details of the agreement can be found in AGG (2009).

AGG builds on several existing measures in Danish legislation which target the agricultural sector and which have already or will in the future reduce the sector's GHG emissions (Rasmussen *et al*. 2009). They include:

- The Action Program for Joint Biogas Plants, launched in 1987 to promote the development of large-scale centralized biogas plants seeking to reduce emissions along with better manure utilization (Hjort-Gregersen 1999; Rasmussen *et al*. 2009).
- Burning of agricultural residues on fields was prohibited since 1989 with the objective to reduce air pollution (Rasmussen *et al*. 2009).
- Three Action Plans for the Aquatic Environment launched in 1987, 1998, and 2004 to reduce contamination of water courses.
- Action Plan for Sustainable Agriculture launched in 1991 which introduced a tightening of the requirements governing the use of farmland manure.
- The Ammonia Action Plan launched in 2001 aimed at optimum manure handling in livestock housing as well as banning surface spreading and a reduction in the time manure is allowed to remain on the ground surface (AAP 2001).

All these initiatives shared the overall aim of reducing nitrogen losses from agricultural activities. These plans included requirements regarding winter green fields, better utilization of manure, re-establishment of wetlands, afforestation, measures on environment-friendly agriculture, expansion of organic farming, improved use of fodder, reduced animal density, use of catch crops, and stricter fertilization requirements (Rasmussen *et al*. 2009), as well as banning surface spreading and a reduction in the time manure is allowed to remain on the ground surface (AAP 2001). Now added to these initiatives within AGG is the Riparian Zone Act which enforces buffer zones free of cultivation, fertilization and pesticide use along all streams and lakes larger than 100 m^2 in rural areas (Ministry of Food, Agriculture and Fisheries of Denmark).

Objective

The purpose of AGG is to ensure that a high level of environment, nature, and climate protection goes hand in hand with modern and competitive agriculture and food industries.

Funding

Between 2009 and 2015, the Danish Government has budgeted DKK 13.5 billion (approx. US$ 2.4 billion) for AGG (AGG, 2009).

Outcomes and impacts of AGG

Danish agricultural industry has succeeded in combining growth with overall reductions in GHG emissions (GreenGrowth 2009) amounting to a 19.4% decrease between 1990 and 2010 (Nielsen *et al*. 2012). Several studies report that these GHG gains have largely been due to reductions in nitrous oxide emissions.

Bennetzen *et al*. (2012) noted that GHG gains were "largely due to national environmental policies focusing on reducing nitrogen application rates, nitrogen losses and improving nitrogen utilization in manure." This supports the conclusion previously reached by Rasmussen *et al*. (2009) who found that during the period from 1990 to 2006, the emission of GHG from agriculture declined from 13 to 9.6 million tonnes CO_2e, a 26% decline, with an expected decrease to 9.4 million tonnes CO_2e in 2025. They concluded that this could "*mainly be explained by improved utilization of nitrogen in manure, a significant fall in the use of fertilizer, and a reduced nitrogen leaching."* These significant GHG gains were largely due to reductions in nitrous oxide emissions from the agricultural sector which have fallen by 31% between 1990 and 2007 (Nielsen *et al*. 2012; Mikkelsen *et al*. 2011).

However, a reduction in methane emissions has also occurred. With a decline in cattle numbers which are regulated by milk quotas, a 5% reduction in methane emission from enteric fermentation was reported between 1990 and 2010 (Nielsen *et al*. 2012). In addition, Dalgaard *et al*. (2011) and Rasmussen *et al*. (2009) point to increased soil carbon sequestration through the use of catch-crops, an increased area under organic farming, wetland re-establishment, the ban on the burning of straw, reduced liming of fields, and increased establishment of perennial plants.

Lessons learned

With the assumption of a sustained food production and an improvement of the productivity in Danish agriculture, Dalgaard *et al*. (2011) conclude "that is it possible to achieve an agricultural production that substantially reduces the GHG emissions by 50-70% and even delivers surplus bioenergy for use in other sectors."

In addition, Dalgaard *et al*. point to the concern that the decline in Danish livestock may eventually lead to increase in livestock production elsewhere in the world where production efficiency might be lower and the associated GHG emissions higher.

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5.4. Kenya Agricultural Carbon Project (KAC)

Background information

In November 2010, the Kenya Agricultural Carbon (KAC) project became the first soil carbon project in African to sign an Emissions Reduction Purchase Agreement (ERPA) with the World Bank's BioCarbon Fund. The project is located in the Kisumu and Kitale districts of Western Kenya, districts which are dominated by subsistence farming on highly degraded farmlands with an average farm size of less than 1 hectare (Woelcke 2012).

The KAC project is being implemented by Vi Agroforestry, a Swedish NGO with more than 25 years of experience in Western Kenya. Vi Agroforestry currently has 27 field officers within the project area, who provide advisory services to participating farmer groups (Shames *et al*. 2012) with whom they have established contracts that include details on rights and obligations with respect to service provisions and carbon revenues (Woelcke 2012).

The project is developing and piloting the 'Adoption of Sustainable Agricultural Land Management' (SALM) methodology under the Voluntary Carbon Standard (Shames *et al*. 2012). Farmers can choose from a range of SALM practices which include improved crop, soil, and water management practices as well as agroforestry innovations, restoration and rehabilitation of degraded land, and improved livestock management (Lager 2011). Because the SALM methodology is in the public domain it can eventually be used for similar projects, leading to lowering transaction costs (Woelcke 2012).

The primary mechanism for project monitoring is the Activity Baseline and Monitoring Survey (ABMS). A sample (5%) of participating farmers completes the ABMS every month. Farmers groups will receive payment according the carbon gains that are estimated from these reports (Shames *et al*. 2012). Vi Agroforestry then sells GHG gains to the BioCarbon Fund (Woelcke 2012). The revenue from carbon credits is distributed between farmers groups (60%), Vi Agroforestry extension operations in the project area (30%), and Vi Agroforestry headquarters in Stockholm to cover administrative costs (10%) (Shames *et al*. 2012).

The goal of the project is to eventually involve around 60,000 households in 3,000 farmer groups, covering an area of approximately 45,000 ha, equally distributed between the two project regions (Lager 2011; Shames *et al*. 2012). Starting from 2009, the goal of Vi Agroforestry is to develop capacities for community-led project management during the first three to six years, leading to communities independently operating their carbon projects. The carbon contracts will operate for nine years while monies for the credits will flow for 20 years until 2029 (Shames *et al*. 2012). Approximately 11,000 farmers per year are planned to be recruited, ending in 2017 (Shames *et al*. 2012).

Projected reductions in GHG emissions are 1.2 million tonnes CO_2e over a period of 20 years, an average of 60,000 tonnes CO_2e per year (Lager 2011) and 1.37 tonnes CO_2e per ha per year (Shames *et al*. 2012).

Objectives

The objective of KAC is to increase crop yields and to enhance smallholder farmers' abilities to respond to climate variability and change. In addition, since the adoption of SALM practices leads to carbon sequestration, "smallholder farmers will be able to access carbon markets and receive additional revenue streams by selling the carbon sequestered" (Woelcke 2012).

Funding

Project donors include the Swedish foundation - Vi Planterar Träd, the Swedish International Development Agency (SIDA), and the World Bank BioCarbon Fund (Shames *et al*. 2012). The World Bank BioCarbon Fund is the credit buyer (Shames *et al*. 2012).

Early outcome and impacts

Given the pioneering nature and the relative recency of this project, it is still too early to assess its success, constraints, and impacts. To date 15,000 farmers in 800 farmer groups, located in six areas in Kitale and Kisumu, have adopted the SALM methodology (Lager 2011). The first payments to farmers are not expected until end of 2012 once the ABMS are verified (Shames *et al*. 2012).

Whilst SALM measures are designed to lead to increased crop yields and agricultural profitability (Shames *et al*. 2012), we were not yet able to find documented evidence to support this, nor indeed of estimated GHG gains that might have accrued thus far. In addition to projected crop yield increases, the project expects a number of spillover benefits to the farmers including increased tree numbers, reduced farmer dependence on fertilizers and pesticides, improved agricultural knowledge and skill as well as improved community cohesion (Shames *et al*. 2012). Again, we could find no documented evidence concerning the extent of these anticipated benefits.

Lessons Learned

Woelcke (2012) suggests that five lessons have emerged from the project to date:

1. "Get the priorities right" – focus project design on smallholder farmers' interests; first come increased crop yields and food security, then carbon sequestration.

2. "Monitor transaction costs" – measurement, reporting, and verification systems should be cost-effective and user-friendly.

3. "Carefully select project developer" – strong extension systems, innovativeness, interest to learn, and technical and financial capacity are key.

4. "Technical assistance and capacity building are key to project success" – providing smallholder farmers access to carbon revenues requires special technical expertise.

5. "Focus on areas with high agricultural potential" – carbon sequestration potential is higher in areas with high biomass growth.

However, the approach used in this pioneering project is not without challenges. For example, Suppan and Sharma (2011) note, amongst other concerns, that "because of the high level of uncertainty associated with this method and the impermanence of greenhouse gas (GHG) reductions [through soil carbon sequestration], the project will discount 60% of the carbon claimed to be sequestered …indeed, according to our analysis of project cost and benefit estimates, the carbon payments are negligible in the Kenya Project: at most a little over $1 per farmer per year for 20 years."

Nevertheless this project is important in that it is piloting an innovative way for small-scale farmers to access carbon markets whilst at the same time seeking to improve farm productivity as well as livelihood resilience. As in any pilot initiative, many useful lessons will be learnt as the project progresses.

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5.5. Niger's Community Action Project for Climate Resilience (CAP)

Background information

Co-financed by GEF and IFAD, Niger's Community action Plan (CAP) was launched in 2003 with the aim of the improving the capacity of local government to design and implement development plans using small capital grants targeted towards improving the livelihoods of local people. It was seen as a way to 'prime the pump' of decentralization in Niger, and although local governments had had little previous experience in such undertakings, they proved 'surprisingly good' at it with funds being successfully allocated to a wide range of local projects. For example, in the first phase, communities built 322 school classrooms for 15,000 students; 153 literacy centers for 6,000 adults; health posts to provide primary care to 300,000 people; and wells and boreholes to provide 170,000 people with access to clean drinking water (World Bank 2010).

CAP also financed more than 1,000 income-generating micro-projects in agriculture, fisheries, and livestock, which benefited an estimated 100,000 people, 80% of whom were women. As a result, nearly 9000 hectares of land were developed with more sustainable land management practices. In evaluating these projects, the World Bank (2010) reported that these micro-projects had led to increased agricultural productivity, increased vegetative cover, increased carbon sequestration, and reduced sedimentation of watercourses, and it had also reduced water erosion in 88% of the sites. World Bank concluded that "CAP works because it makes the most of local abilities and builds on the pride that people take in managing the development process by themselves."

In November 2010, Niger's Strategic Programme for Climate Resilience (SPCR) was approved. SPCR includes five investment projects, one of which is the Community Action Project for Climate Resilience (CAPCR) (World Bank 2011a).

Given the proven success of the 1st phase of CAP in Niger, CAPCR is aligned with and will strengthen the activities of the 2nd phase. It will be implemented between 2012 and 2017 (CIF 2010). It focuses on scaling up support for sustainable land and water management as well as improving weather services and social safety nets (CSA report 2011). CAPCR will support best land and water management practices for improved food security while integrating and scaling up lessons learned from recent and current programs (CIF 2010).

Objectives

CAPCR's objective of "Improving the resilience of the populations and of production systems to climate change and variability, in order to increase national food security" will be achieved through three separate, but complementary components.

Component 1

- Theme: Mainstreaming climate resilience into development strategies at national and local levels (US$5 million).
- Expected Outcome: Climate resilience is incorporated into development programs and investment plans.
- Beneficiaries: The activities are expected to benefit all Nigeriens due to the impact of climate-oriented policies and greater general awareness of climate risks.

Component 2

- Theme: Integrating climate resilience practices into agro-silvo-pastoral systems and local populations' social protection measures (US$53 million).
- Expected Outcome: An improved resilience of production systems to climate change.
- Beneficiaries: The potential direct beneficiaries of Component 2 are a population of about 2 million people which represents around 310,000 households amounting to about 13% of the total population of Niger.

Component 3

- Theme: Ensuring coordination of all the activities of the project, including monitoring and evaluation activities, with SPCR overall strategic coordination (US$5 million).
- Expected Outcome: Appropriate information concerning CAPRC activities is shared at national and international levels.

Funding

CAPCR will be financed through US$35 million grant and US$28 million concessional loan. Each will be provided by the Pilot Program for Climate Resilience developed under the Strategic Climate Fund, with the International Bank for Reconstruction and Development

(IBRD) acting as the implementing entity of the Strategic Climate Fund for this Project (World Bank 2011a).

Lessons learned

Whilst it is too soon to draw explicit lessons from CAPCR with regard to what extent it will contribute to building the climate resilience of Nigerien production systems and hence the livelihood resilience of local communities as well as possibly sequestering above and below ground carbon, three generic lessons are apparent, namely:

1. Development initiatives that are based on a decentralized and participatory decision making process that allows local communities to choose their own priorities and manage their implementation, run a high chance of success and of achieving the desired impacts.

2. Such development initiatives will almost always attract further funding and support to scale up initial successes, especially when they form part of a Government's Strategic plan, as has been the case here.

3. Many initiatives claim above and below ground carbon sequestration, as in the World Bank report (2010). We suggest that more attention be paid to measuring and documenting actual emissions/sequestration so that CSA and possible associated financing can indeed be justified.

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5.6. Participatory Forest Management in Tanzania

James Kinyangi

Background information

Land clearance and small-scale subsistence farming is one of the main causes of forest cover loss in Tanzania. Between 1995 and 2005, annual loss of forests due to agricultural expansion, livestock grazing, wild fires, and utilization of wood resources was between 130,000 ha and 500,000 ha per year (FAO, 2009).

Since the late 1990s, the government of Tanzania has pursued forest reform policies that promote community participation in forest management as a way to secure natural forests against degradation from human activity, as well as enhancing the benefits of participatory forest management (PFM) to thousands of villages located within the margins of forests and natural woodlands. The Forest Policy of 1998 provides that unreserved forests or woodlands reside under local jurisdiction as village forest reserves, while the Forest Act of 2002 enacts forest tenure categories for production and protection (MNRT, 1998; MNRT, 2002). Through these two approaches, the government of Tanzania provides the legal basis for communities to own and manage forest resources on village lands through Community based Forest Management (CBFM) or jointly manage forest resources (JFM) within government forest reserves.

At the sub-national level, management of community forests in Tanzania is a joint effort between the district councils and the local village councils. This allows for co-management and a benefit sharing mechanism; where the villages retain a portion of the monies from fees, licenses, and permits paid in respect of the local bye-laws (Robinson and Lokina, 2012).

From a Climate Smart Agriculture perspective therefore, large-scale success in PFM is important for two reasons. Firstly, it mitigates against agricultural expansion within forest margins which is a major cause of deforestation and forest degradation, and hence loss of carbon sinks. Secondly, PFM allows for the diversification of agricultural livelihood strategies through legal access to a range of forest products. For example, Monela *et al*. (2000) estimated that honey, charcoal, and fuel wood harvested from managed forest contributed up to 58% of cash income of farmers in six villages surveyed in their study. Under both JFM and CBFM, a number of these are prohibited, for example fire management, settlement for farming, and charcoal production (Pfliegner, 2010). However, there are livelihood activities related to food security that are permitted; such as gathering fruits and vegetables, seasonal grazing of livestock, and bee-keeping.

Objectives

PFM's objectives are to improve forest quality through sustainable management practices; improve livelihoods and food security through increased forest revenues and secure supply of subsistence forest products (Blomney and Ramadhani, 2006) while allowing for forest governance at village and district levels through effective and accountable natural resource management institutions.

Funding

Denmark DANIDA, Norway NORAD, Sweden SIDA, Finland FINNIDA, The World Bank and The UNDP-GEF are all program donors (MNRT, 2006). PFM also receives support from the government, and local and international NGOs making it a truly multi-stakeholder engagement. The program has a strong ownership component through the local participating village communities and the district councils that are involved in monitoring.

Outcomes and impacts of PFM

According to MNRT, (2008), a total of 25% of both reserved and unreserved forest in Tanzania were covered under PFM, either through joint government-to-community or community-based management. With 7,000 participating households, these approaches are scaled up to reach nearly 600,000 beneficiaries in more than 60 districts on 4.12 million ha of reserved and unreserved forest land.

PFM has resulted in the decentralization of governance of forests to local village user groups, providing new opportunities for strengthening policies on land with enhanced tenure rights for forest margin dwellers in Tanzania (Robinson and Lokina, 2011). Under existing governance arrangements in Tanzania, women exercise greater responsibilities for crop production as well as the collection and preservation of wild foods, medicine, and clean water.

Lessons learned

The government of Tanzania has been keen to expand the role of village institutions in decision making, devolving power from the center to the periphery. This is a key feature of building adaptive capacity for local communities. Other positive attributes have been highlighted by Wily and Dewees (2001), for example the capacity of government institutions for action learning has been improved significantly.

Lokina *et al*. (2008) have recommended a number of actions:

- PFM should be implemented with a landscape approach to avoid ‘leakage’ by eliminating access to alternative forests by local communities who have been displaced from PFM sites. The establishment of woodlots and expanded tree cropping on private holdings should be encouraged in order to ease demand for access to food and timber products at managed forest sites;
- Village communities’ access to information and skills should be increased, and incentives as well as delegated authority should be provided in order to protect PFM sites given that greater food and income benefits accrue from better managed forests.
- The need to realize that challenges arise when the value of forests is in conflict with local communities, such that they bear the ‘cost’ of reduced access to PFM sites. For this reason, incentive mechanisms to increase revenues from PFM sites are proposed. Examples include payments for environmental services and incomes from eligible afforestation/reforestation mitigation projects under the Clean Development Mechanism or the Reductions in Emissions from Deforestation and Forest Degradation (REDD).
- For the schemes in Tanzania, a challenge remains as to how village communities involved in PFM can be paid for the carbon sinks that they protect (Schaafsma *et al*. 2011).

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5.7. Morocco Green Plan (PMV)

Background information

Agriculture in Morocco accounts for 16% of the GDP and is the principal source of income for 43% of the population (Badraoui & Dahan 2010). With 80% of its territory being arid to semi-arid, agriculture is prone to large season-to-season variability in production (Yohe *et al*. 2006). Designed to usher in a substantial shift away from a highly protected market to a more open market-oriented agriculture, the Government launched the Moroccan Green Plan (Plan Maroc Vert, PMV) in 2008 with a planned investment of US$ 17 billion by 2020. PMV lays out a series of public sector reforms aiming to transform the agricultural sector into a driving force for broad-based economic and social growth in rural areas.

PMV seeks to address the development of the entire agricultural production chain, from input supplies to product marketing. The plan also recognizes the contributions of farmers and their organizations to the success of agricultural development projects and stresses the importance of training to help farmers implement their projects (Balaghi *et al*. 2011). Through PMV, the government hopes to create one million new agricultural jobs and to improve the incomes of three million rural poor by 2-3 fold.

The plan is built on two pillars: Pillar 1 promotes a modern and competitive agriculture adapted to markets and Pillar 2 is dedicated to combating rural poverty through increasing the agricultural revenues of the most vulnerable farmers in marginal areas.

In 2011, the Government of Morocco and the World Bank, through the Special Climate Change Fund of the Global Environment Facility (GEF), are co-financing a project entitled 'Integrating Climate Change into the Plan Maroc Vert (PMV).' The project aims to strengthen the capacity of institutions and small-scale farmers to integrate climate change adaptation measures in PMV projects (World Bank 2011).

Objectives

PMV has four objectives, namely to: (i) reduce poverty though the improvement of small famers incomes, (ii) ensure food security, (iii) protect natural resources whilst ensuring the long term sustainability of the sector, and (iv) integrate Morocco's agriculture into national and international markets.

The plan expects to double agriculture's value added within a decade and to reach an annual GDP of US$ 11.5 billion (Saoud 2011).

Funding

In 2010 the EU signed a financing agreement for € 70 million to support the implementation of PMV (ENPI 2010). In May 2011The World Bank approved a US$ 4.35 million grant from the Special Climate Change Fund of the Global Environment Facility (GEF) to support farmers and institutions in mainstreaming climate change adaptation measures within projects implemented by PMV. In 2012 The African Development Bank granted the Government of Morocco € 105 million (nuqudy 2012), and France also approved a low-interest loan and a € 300,000 grant (AFD 2012). In addition, a € 42.5 million loan from the European Investment Bank will help to finance the National Irrigation Water Saving Programme's priority action (ANSA 2012). The Government of Morocco will co-finance the grant with an investment of US$ 27 million (IIDS 2011).

Early outcomes and impact

By 2011, 64 projects within the food production sector have been launched, covering 132,000 hectares with an investment of US$ 2 billion. In addition, 108 projects which address high added value agriculture have been launched covering 336,000 hectares with an investment of US$ 570 million. Compared to the period 2005-2007, production has increase by 190% in the olive sector, by 20% for citrus production, 52% for cereals, 45% for dates, and 48% for red meat (Ministry of Agriculture 2011).

Ex ante analysis projects that PMV has the potential to achieve GHG gains of 63.5 million tCO_2e over 20 years, equivalent to 1.44 tCO_2e/ha/year. These gains are expected largely from the sequestration of soil carbon through improved agronomic practices (FAO 2012).

Lessons learned

PMV demonstrates a major and integrated commitment by the Government of Morocco to modernize its agricultural sector and to enhance the livelihoods of those that the sector supports. The government itself has invested substantive funds in this initiative. In addition, and doubtless because of this commitment, it has received substantive and continuing support from major donor agencies.

Whist it is encouraging that the FAO (2102) has drawn attention to the potential of GHG gains within PMV, we were unable to find any evidence that efforts are being made to measure the extent of GHG gains on the ground. Given the recent launching of the project 'Integrating Climate Change into the Plan Maroc Vert (PMV)' (World Bank 2011), we hope that this concern will be addressed.

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5.8. Weather Based Crop Insurance Scheme (WBCIS), India

Background information

Extreme weather conditions (e.g. droughts, intense rainfall, floods, extreme heat) are expected to become more frequent and of greater severity. Such weather extremes result in crisis and hardship for farming families world-wide. Perhaps as important, particularly in the developing world, is "lost opportunity", since resource poor farmers are often unwilling to invest in the face of uncertainty, given that their investments of time and resources could be lost (Cooper *et al*. 2008).

As a result, there are many different types of insurances schemes available worldwide in the agricultural sector which protect farmers against weather related risks. The availability of such insurance schemes potentially enhances the risk-taking capacity of farmers, banks, micro-finance lenders, and agro-based industries (Barrett 2007). In this study, we refer to two types of insurances currently available in India, namely Area Yield Index Insurance and Weather Index Insurance.

Area Yield Index Insurance: Farmers within a given area (sub-district) are insured against yield loss below a certain percent of the longer term rolling average yield for the area. Yields are verified independently each year on a sample of farms within the sub-district. It is suitable for events such as widespread drought and has relatively low costs as yields do not require verification on each farm. However, it assumes the same average effect across all farms within the sub-district, and can also result in delayed pay-outs due to the yield verification process.

Weather Index Insurance: Farmers within a given district, determined by the proximity of a weather station, are insured against crop yield loss using a specified 'weather index'. They receive an automatic payout when the weather index goes above or below an established level. The insurance company does not need to visit farmers' fields to assess losses; instead it uses data from weather stations in the area to determine pay-outs. It is low cost as no yield verification is needed, and also pay-outs can be made faster – a feature that reduces or avoids distress sales of assets.

An Area Yield based country-wide Comprehensive Crop Insurance Scheme (CCIS) was introduced in India in 1985, which was subsequently replaced by the National Agriculture

Insurance Scheme (NAIS) in 1999. Since that time, NAIS has become the world's largest crop insurance program with over 20 million farmers insured annually (Mahul *et al*. 2012). Because of administered premium rates it is not open to private sector competition and is currently administrated by the Agricultural Insurance Company of India (AICI) (Rao 2011). NAIS has been criticized for its potential open-ended liabilities for the government, major delays in claim payments for farmers, inefficiency in the process of crop yield estimation (Mahul 2012) and the possible 'moral hazard' of farmers deliberately farming poorly in order to claim insurance (Government of India 2011).

As an alternative to NAIS, the Weather Based Crop Insurance Scheme (WBCIS) was launched as a pilot in 2007 (Government of India 2011). WBCIS is a publicly subsidized index-based insurance scheme and is open for private sector insurance companies to compete with AICI (Clarke *et al*. 2012). The government has in 2010 introduced another pilot in 50 districts of the country, a 'modified version of NAIS' with improved features, and risk based premiums supported by up-front subsidies in premium with private sector competition.

Objective

Weather Based Crop Insurance aims to mitigate the hardship of the insured farmers against the possibility of financial loss associated with low crop yields or crop failure resulting from adverse weather conditions.

Early outcomes and impacts of WBCIS

In the 2010-11 agricultural year over 9 million Indian farmers held WBCIS policies with premium volume of over US$ 258 million (premium volume includes both farmer premium and government premium subsidies) and total sum insured over US$ 3.17 billion. The volume of paid claims in 2011 amounted to US$ 125 million (Clarke *et al*. 2012). These policies covered over 40 different crops and 9.5 million hectares (Rao, 2011). For 2011-12, over 11.6 million farmers held the policies covering a risk valued at US$ 4.18 billion with a premium volume of US$ 370 million.

Clarke *et al*. (2012) note that having insurance is mandatory for farmers borrowing money from a financial institution in India. The considerable majority of WBCIS-covered farmers are obligated borrowing farmers. This, combined with the faster claim settlement and more foreseeable and close-ended liabilities for the government has resulted in the extensive and ongoing increase in farmers insured under WBCIS since 2007.

The overall claim ratio based on five years' of experience is little over 60%, and in most cases the payments are made within 45 days from the end of the risk period as promised in the contract. The majority of payments during the Kharif season (June-October) are due to low rainfall and dry spells, whilst in the Rabi or winter season, the majority of payments are due to frost, excessive heat, and unseasonal rainfall (K.N. Rao: Pers. Com.)

Lessons learned

The Weather Based Crop Insurance Scheme in India, although widely taken up by farmers, is still faced by several challenges:

- Designing a proxy weather index with the ability to realistically predict crop yield loss is challenging, but is essential in reducing 'basis risk', since currently farmers often experience losses without receiving payout, or vice versa (Rao, 2011).
- Reducing basis risk should also be addressed by increasing the density of weather stations. A survey evaluating WBCIS showed that the location of weather stations for claim settlement is the paramount factor concerning the confidence of 77% of farmers in relation to weather based insurance (Government of India, 2011). AICI is currently running pilot projects to incorporate modeled weather data at 3x3 km grid into product design and payout determination in order to significantly minimize the basis risk.
- According to the World Bank (2011), WBSIC products are not only subject to high basis risk, but also rely on historical weather data. This could lead to systematic underpricing since the frequency of adverse weather impacts are projected to increase with climate change.
- There appears little incentive for insurers to design simple, transparent contracts easily understandable to farmers due to the mandatory nature of WBCIS (Clarke *et al*. 2012).
- The task of appraising the diverse portfolio of weather insurances is very specialized and lies in the nexus of agriculture, statistics, meteorology, and financial risk management. Finding skilled personal is challenging (Government of India, 2011).

In spite of these challenges, the following more generic climate related lessons associated with weather index insurance schemes in general seem important. Firstly, the affordable (or subsidized) availability of such insurance to small-scale and risk prone farmers is clearly beneficial in enhancing their risk taking capacity, thus enabling them to avoid 'lost opportunities' associated with their inherently risk-averse nature. Secondly, the premiums that farmers currently pay are calculated using long term historical weather data to assess the likely frequency of adverse weather events in any particular sub-district. Given that the frequency and severity of such events is projected to increase due to global warming, it is very probable that the premiums of weather index insurance schemes may go up.

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5.9. Integrated Agrometeorological Advisory Services (IAAS), India

Background information

The Indian Meteorological Department (IMD) first started providing weather services to farmers over 65 years ago in 1945, broadcast by All India Radio in the form of a Farmers' Weather Bulletin. From the start, this initiative had the intent of helping farmers cope better with the impacts of season-to-season variability of weather events (Rathore *et al*. 2011). In 1976, IMD started to collaborate with all the State Governments across India in launching a more comprehensive information system entitled the Agro-meteorological Advisory Service (IMD NA). In 2007, and in response to an increasing demand of Indian farmers for this type of service, the Agro-meteorological Advisory Service was further upgraded when IMD launched the Integrated Agrometeorological Advisory Service (IMD NA).

The Integrated Agrometeorological Advisory Service (IAAS) is an interdisciplinary and multi-institutional project which involves several stakeholders such as agricultural universities, research units, NGO's, and media agencies (Rathore *et al*. 2011). This multi-stakeholder characteristic allows the development of a multi-tier structure of products, namely (i) a meteorological component consisting of weather observation and forecasting for the next 5 days, (ii) an agricultural component, which identifies 'weather sensitive stresses' and converts weather forecasts into appropriate farm-level advisories, (iii) an extension component, with two-way communication between farmers, agricultural scientists, and national forecasters, and (iv) an information dissemination component employing mass media (Rathore *et al*. 2011).

IAAS bulletins are issued at three institutional levels, National, State, and District. The latter targets farmers in the respective districts and is provided by Agromet Field Units (AMFUs) located within State Agricultural Universities (IMD NA). Currently there are 130 such AMFUs, covering all agro-climatic zones in India (Rathore *et al*. 2011). Experts at the AMFUs receive weather forecasts and convert them into agro-advisories, which in turn are formulated as specific bulletins containing weather sensitive management advisories outlining specific agricultural actions (IMD NA) in a readily understood format and language (Rathore *et al*. 2011). These are communicated to farmers through SMS, radio, newspapers, etc. (Kulthe 2012). In addition, each AMFU is associated with a group of 50 to 100 local farmers who provide feedback on the services provided (Brara 2011).

Objective

"The IAAS aims to generate agro-meteorological information (weather forecasts and agro-advisories) while developing suitable dissemination systems to improve crop and livestock productivity" (Kulthe 2012).

Early outcomes and impacts of IAAS

Whilst it is still relatively early to fully evaluate the impact of IAAS, some information is available. According to Brara (2012) IAAS provides services which include detailed weather forecasts, market data, pricing information, and advisory services to over 2.5 million farmers, largely through their mobile phones. These services have led to increases in farm productivity, partly by reducing weather related losses, but also through generating higher incomes. To date, the program has had an estimated economic impact of more than US$10 billion (Bhalla 2012).

A pilot study conducted by Maini & Rathore (2011) assessed the economic impact of IAAS on selected crops (food grains, oilseeds, cash crops, fruits and vegetables). They found that farmers who used IAAS's services had a 10-15% net benefit of overall yield and a 2-5% reduction in cost of cultivation compared to non-IAAS farmers. They also noted that IAAS had encouraged farmers to adopt modern agricultural production technologies and practices, promoted weather-based irrigation management and pest/disease management, and had also increased use of improved post-harvest technologies.

Lessons learned

This case exhibits the structure and implementation of a successful advisory service; namely the integration of weather and climate information with agricultural information in order to produce advisories focused on specific farmer needs. It is deployed with far-reaching communication methods and two-way interaction between farmer groups and IAAS through the AMFU's (Kulthe 2012).

The provision of 'near future' (the next 5-day period) weather information to farmers, coupled with agricultural advice on farm production enterprises that are weather sensitive, is an excellent example of helping farmers to cope better with *current* climate-induced risks. However, the National Council of Applied Economic Research suggest that the services of IAAS are currently insufficient with regard to meeting the mounting challenge of providing weather services in the face of climate change. They also note that the countries agro-meteorological infrastructure, consisting of 130 AMFUs, are enormously underdeveloped and require upgrades and widespread scaling-up (NCAER, 2010).

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5.10. Ethiopian Productive Safety Net Programme

Sidsel F. Cappiello and Peter Cooper

Background information

Accepting that food insecurity in Ethiopia had become more chronic than temporal, the Ethiopian Government launched the Productive Safety Nets Programme (PSNP) in 2005 (Sabates-Wheeler and Devereux 2010), thus replacing continual appeals for emergency food aid and *ad hoc* responses with a more predictable safety net.

PSNP is a social transfer program in which beneficiaries receive both cash and food support. Targeted households should have experienced at least three months of food gap per year in the last three years, be acutely food-insecure, and lack external social support (GFDRE 2010 in Berhane *et al*. 2011). The transfers are distributed to both direct and indirect support beneficiaries. The direct support beneficiaries (84% in 2008) are required to attend temporary employment in 'public workfare projects', whilst the indirect support beneficiaries who are unable to contribute to public works due to labor constraints are not required to work (Berhane *et al*. 2011; Sabates-Wheeler & Devereux 2010). As such, PSNP provides a planned systematic approach in addressing chronic and seasonal hunger in Ethiopia (Berhane *et al*. 2011; World Bank 2011a).

The 'public workfare projects' are in accordance with both local district (woreda's) development plans and with the Ethiopian Ministry of Agriculture and Rural Development procedures on 'Community-Based Participatory Watershed Development' (CBPWD). They include, for example, the establishment of area enclosures, woodlots, construction of hillside terraces, shallow wells and ponds, and stream diversion for irrigation (Berhane *et al*. 2011).

PSNP is complemented by the Household Asset Building Programme (HABP) which seeks to improve household's income generating and asset holding abilities "while the PSNP is designed to protect existing assets and ensure a basic level of food consumption, the HABP is designed to assist households in increasing incomes generated from agricultural activities and to build up assets so that they will be able to 'graduate' off the PSNP program" (Berhane *et al*. 2011). A household has graduated from PSNP when it is deemed to have moved from being depended on assistance to a 'food sufficient' situation without the need of external support (Berhane *et al*. 2011).

Objectives

PSNP's objectives are to provide transfers to the chronically food insecure population in a way that prevents asset depletion at household level and creates productive assets at community level (World Bank 2011b).

Funding

Canada, Ireland, Sweden, UK, US, EU, The World Bank and The World Food Programme are all program donors (Brown *et al*. 2008). PSNP is almost fully funded by external donors. However the Ethiopian government has, from the beginning, had a strong ownership over the program (Devereux and White 2010).

Outcomes and impacts of PSNP

PSNP has been implemented in 7 out of Ethiopia's 10 Regions and in 244 of over 500 woredas (Brown *et al*. 2008). It is the largest social protection program in Sub-Saharan Africa outside of South Africa and has reached around 8 million people or 12% of the population in Ethiopia (Devereux and White 2010).

Berhane *et al*. (2011) found that in 2010 70% of PSNP households in the survey perceived their overall economic condition as better or the same compared to the previous year, an increase from 41% in 2008. The survey also found that from 2004-2010, the level of assets had increased and distress sales had declined, regardless of beneficiary type.

Jones *et al*. (2010) studied the gender aspect of the PSNP and found that PSNP "has had a range of positive, practical impacts on women and their families. For example, the program is smoothing food consumption patterns, facilitating school enrolment, providing basic necessities and reducing their anxieties." They also found that, from a community level point of view, public work projects have led to substantial benefits for all, PSNP beneficiaries as well as non-beneficiaries.

Andersson *et al*. (2009) evaluated the impacts of the PSNP on household's holdings of livestock and forest assets and found no disinvest in PSNP beneficiary households in keeping livestock or trees. In fact, PSNP participation had resulted in increased forestry activity.

Lessons learned

Political commitment has been essential in the implementation of PSNP. Ethiopian government leaders had played a key role in aspiring to break Ethiopia's dependency on food aid and have been granted with steady, long-term financing which gave them the incentive to invest politically in the program (Brown *et al*. 2008).

Berhane *et al*. (2011) have noted several important points:

- The number of support beneficiaries graduating from the program has been relatively little. Many respondents in the survey believed that to obtain high levels of graduation, large investments in agricultural technologies and irrigation at a community-level are vital. Whilst support to newly PSNP graduates is available, there is little indication of graduate households receiving this support.
- The majority of the respondent households (56-80%) perceived construction of water-harvesting infrastructure as being useful to the community, but are not finding natural resource management such as soil and water conservation activities as beneficial. Regional and woreda officials perceive the construction of hillside terraces, rock dams, enclosures for growing high value fodder tree, roads, and tree planting as supporting peoples livelihood the most.
- In contrast to Jones *et al*. (2010) they found that women participating in the program might be put under considerable pressures by fulfilling their required participation in the public work in addition to their domestic work.
- Due to uncertainty about prices, lack of food availability on the market, deliberate price hiking by traders, the vast majority of the PSNP beneficiaries strongly prefer food transfer to cash transfers.
- A major concern in the program has been the payment predictability. However, the predictability has improved from year to year, despite ongoing uncertainty regarding payment dates by many respondents in the survey.

From a CSA perspective, PSNP has helped a very large number of Ethiopians cope better with climate-induced risks, although as noted by Berhane *et al*. (2011) challenges in the implementation of PSNP remain. However, whilst several reports refer to the undoubted potential of the workfare projects to sequester additional above and below ground carbon, we were unable to find evidence that this had been measured or even estimated. If such social safety net programs are to become linked with carbon or mitigation finance, this will have to be rectified.

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5.11. Sustainable Intensification of Rice Production in Vietnam

Background information

Sustainable Intensification of Rice Production (SIR) is a set of alternative crop management practices designed to benefit farmers with small landholdings. SIR increases the productivity of rice by changing the management of plants, soil, water and nutrients (SIR RICE 2012a) through optimizing the performance of the individual rice plant rather than relying on maximizing inputs. The choice of management steps involved in SIR is described in WWF-ICRISAT Project (2010). Benefits of SIR have already been seen in 40 countries, with increased production of both improved and local rice varieties. They include up to a 100% increase in yields, up to a 90% reduction in required seed and up to 50% water savings (SIR RICE 2012a), while also helping to reduce fertilizer and pesticides inputs (vietnamsri 2008).

SIR offers two important benefits that have significant climate implications if applied on a large-scale (WWF-ICRISAT Project 2010):

1. *Reduced demand for water*. Contrasted with continuously flooded paddy rice, SIR recommends draining of paddy fields several times during the growing season with small applications of water, or alternate wetting and drying during the growth period and just 1-2 cm of water on fields after the plants flower. The lower water requirements for the SIR practice imply that farmers can continue to grow rice in regions facing diminishing water availability (WWF-ICRISAT Project 2010).

2. *Reduced methane gas emissions*. SIR results in paddy soils being intermittently and mostly aerobic thus substantially reducing methane emissions (Nguyen *et al*. 2007). A study by the China Academy of Sciences calculated that methane emissions would be reduced by almost one-third annually if all of the continuously flooded rice fields were drained at least once during the growing season and rice straw was returned to the soil in the off season (Yan *et al*. 2009). Field studies at the Bogor Agricultural University in Indonesia also showed that SRI methods significantly reduce methane emissions (WWF-ICRISAT Project 2010). However, the creation of aerobic conditions through intermittent drying will also increase nitrous oxide emissions (Zou *et al*. 2005).

A successful pilot in Dai Nghia commune in Vietnam in 2006 marked the launch of the SIR extension partnership between Oxfam and Vietnam's Plant Protection Department (PPD) and in 2007 the Ministry of Agriculture and Rural Development in Vietnam formally acknowledged SIR as “a technical advance”. With further support from Oxfam America and in collaboration with Centre for Sustainable Rural Development (SRD), PPD launched a nationwide SRI dissemination effort (SIR RICE 2012b).

Objective

To further expand the SIR rice production of Vietnamese small-holder farmers through community-led agricultural development, while managing soil and water resources more efficiently and sustainably.

Funding

The current expansion of the SIR initiative is funded through a joint effort between the Vietnamese Government and Oxfam (Ngô Tiến Dũng *et al*. 2011). At the start of 2011, the government allocated US$ 383,000 in the six program provinces to support the further dissemination of SRI and other low-input, low-carbon agricultural methods. This was one-third more than Oxfam’s contribution (Castillo *et al*. 2012)

Outcomes and impacts of SRI

Only four after its launch, in late 2011, the Ministry of Agriculture and Rural Development reported that over 1 million farmers (about 10% of all rice growers in Vietnam) were using the SIR approach on 185,000 ha across 22 provinces (SIR RICE 2012b) with the number of farmers using SIR practices in Vietnam tripling since 2009 (Seang 2011).

Vietnamese SIR farmers have benefitted in several ways. They have increased their yields by 9-15% while reducing inputs compared to conventional practice using 70-75% less seed, 20-25% less nitrogen fertilizer, and 33% less water. All of which has resulted in an estimated extra income of US$ 95-260 per hectare per crop season. In addition, farmers report positive changes to their health as a result of less use of pesticides, herbicides, and chemical fertilizers (Castillo *et al*. 2012).

Lessons learned

- Whilst the main objective of this initiative was increased and more efficient rice production, it is clear that the additional climate related impacts of reduced water use and methane emissions are also very important. Estimates of lower water use have been documented in Vietnam, but whilst studies elsewhere have shown SIR reduces methane emissions, it appears that such studies have not yet been done in Vietnam. It would seem important to do so to give even greater momentum and possibly climate related funding support to this development initiative. Such studies should look at both methane and nitrous oxide emissions.

- In a policy brief titled 'Learning from the System of Rice Intensification in Northern Vietnam", Castello *et al*. (2012) emphasized the important contribution to success of three interlinked phases, namely: (i) local testing and confirmation of the potential of SIR, (ii) expanding upon experience and the evidence base to build a critical mass using Farmer Field Schools (FFS) and extensive farmer-to-farmer extension, and (iii) aligning with the government and mobilizing resources though well documented field results and strong advocacy.
- Castillo *et al*. (2012) also noted that women farmers, who made up 70% of participants in FFS, proved to be better trainers than men. After participating in an FFS, each woman helped between five to eight other farmers adopt SIR principles, while every FFS male participant helped only one to three.

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5.12. Farmer Managed Natural Regeneration in Niger.

Background information

In recent decades many studies have documented a remarkable and continuing increase in ground cover and tree numbers in Southern Niger, an increase that cannot alone be accounted for by the cyclical increase in rainfall that has followed the severe droughts of the 1970's and 1980's (Haglund *et al*. 2011), as much as by a change in farmers' tree management practices (Garrity *et al*. 2010; Reij *et al*. 2009; Tougiani *et al*. 2009; UNDP 2008). Reij *et al*. (2010) suggest that this 're-greening' movement might be one of the largest-scale agro-environmental transformations in Africa.

What led to this extraordinary achievement in one of the poorest countries in the world?

For centuries, Niger's farmers had been practicing a method of woodland management by selecting, protecting and pruning re-growth from living tree rootstock, an approach that became known in the early 1980's as 'Farmer Managed Natural Regeneration' (FMNR) (Tougiani *et al*. 2009). In the mid-1980's FMNR became a component of a development project (Maradi Integrated Development Project). However, a new feature of this traditional woodland management approach, pioneered by farmers in Niger and the intermediary organizations that assisted them, was to incorporate FMNR into agricultural cropland and to manage trees as part of a farm enterprise (UNDP 2008). By 1985, 500,000 trees in 95 villages had been regenerated and protected (Rinaudo 2008).

Given the early evident successes, local, national and internationals partners continued to collaborate in facilitating the scaling up of FMNR, largely in Maradi and Zinder regions of southern Niger, but also to a lesser extent in the other regions of Tahoua, Niamey and Dosso (Reij *et al*. 2009).

Impacts of FMNR

By 2008, an estimated five million hectares of once infertile land has been transformed through FMNR practices (Rinaudo 2008; Reij *et al*. 2009; Tougiani *et al*. 2009). Reij *et al*. (2009) estimate that this has led to an addition of about 200 million new trees (*Strychnos spinosa, Balanites aegyptiaca, Boscia senegalensis, Ziziphus spp., Annona senegalensis, Poupartia birrea* and *Faidherbia albida*) to Niger's total tree stock and argues that this large-scale transformation has reduced soil erosion, increased production (both crops and tree-related products), created new income opportunities, and reduced the incentive to migrate away from farms.

According to Reji *et al*. (2009) FMNR has both direct and indirect impacts on household food security. Directly by increasing the availability of food via higher crop yields, FMNR fields contribute an additional estimated 500,000 tonnes of cereals, affecting around 2.5 million people. The indirect impact comes from an increase in tree fodder supply, allowing farmers to keep and maintain more livestock. Larwanou and Adam (2008 in Garrity *et al*. 2010) estimated the aggregated value of FMNR resulting from improved soil fertility, fodder, food, and firewood, as a minimum of US$ 56/ha/ year, leading to a total annual production value of US$ 280 million.

Haglund *et al*. (2011) also point out that FMNR has significant climate change implications through (i) the large-scale sequestration of atmospheric carbon by trees and (ii) reduced loss of topsoil through wind and water erosion. He also suggests that since FMNR is associated with more diverse livelihood portfolios, families may be able to cope better with both current and future climate-induced risks.

Lessons learned

Several factors have contributed to this success:

- FMNR is a simple, low-cost practice encouraging natural tree re-growth by selecting, pruning, and protecting naturally regenerating trees (Tougiani *et al*. 2009). By using living rootstock, FMNR bypasses obstacles related to replanting trees in this region (UNDP 2008).
- The method is flexible, adapting to farmers' situations and needs (Garrity *et al*. 2010).
- FMNR increases the farmers' supply of multiple products: fuel, food, medicine and fodder – products farming households can either consume or sell (Garrity *et al*. 2010), especially benefiting women (UNPD 2008).
- Adoption of FMNR was associated with soil type, access to market and level of farmer education (Haglund *et al*. 2011). They noted that FMNR is associated with increased household income, crop and tree diversity and lower migration rates, however not with an increase in crop yield in their survey area.

- Advocacy and a change in policy were important. The spread of FMNR was further stimulated after the Nigerien Government eased restrictive national forestry regulations in the 1990s and again in 2004 thus granting the farmers 'rights' to the trees that they protected, rights that had hitherto belonged to the Government (Reij *et al*. 2009; Garrity *et al*. 2010).

Without doubt, the planting of about 200 million new trees (Reij *et al*. 2009) must have had substantial implications for above and below ground carbon sequestration. However, no measurements appear to have been made to quantify this important climate change mitigation impact of FMNR. It would seem important to do so to give even greater momentum and possibly climate related funding support to this already successful development initiative.

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5.13. Grain for Green Programme in China: A case study of the Loess Plateau

Background information

China's Grain for Green Programme (GGP) was launched in 1999 in response to a series of devastating floods (Zhou *et al*. 2012). Across China, the scale of implementation of GGP is large with 120 million farmers being involved in the conversion of over 9 million ha of sloping land. It is China's first payment scheme for ecosystem services (Lü *et al*. 2012) and it is based on a cropland set-aside program. The main criterion for inclusion is steepness of slope, targeting lands with 15 degrees of slope or more. The program encourages three types of land use conversion – cropland to forest, cropland to grassland, and wasteland to forest (Zhou *et al*. 2012). Participating households are compensated according to the amount of farmland they set aside with in-kind grains provision, cash payments, and free seedlings (Uchida *et al*. 2007). Grain (between 1,500-2,250 kg/ha/year) and cash (between RMB 2,100-3,150/ha/year) are distributed once a year upon inspection, while the seedlings are provided at the beginning of participation. Recently, the in-kind grain compensation has been converted into a cash payment (Gauvin *et al*. 2010).

The Loess Plateau was identified as a priority region for the GGP. Located in the upper and middle reaches of the China's Yellow River, the Loess Plateau covers a total area of 624,000 km^2. It has a 2000-year-old history of agricultural activity; however, population pressure and exploitation have led to severe land degradation (Chen *et al*. 2007; Zhou *et al*. 2012), with over 60% of the plateau facing serious soil erosion and water runoff. Chen *et al*. (2007) estimated that the loss of cultivated land to soil erosion had an economic value of over RMB 10 billion (~US$ 1.28 billion). In addition, a recent analysis of historical weather data (1951-2008) from 85 weather stations across the Loess Plateau has shown that the climate has exhibited a significant warming and drying trend. Precipitation was found to decrease annually by an average of 0.97 mm and temperature was found to increase annually by an average of 0.02°C (Lu *et al*. 2012).

Objectives

The GGP has two objectives: Firstly, to reduce erosion dual by restoring forest and grasslands on low-yielding, sloping cropland and secondly, to help alleviate poverty (State Forestry Administration (2002) in Gauvin *et al*. 2010).

Funding

Across China, the GGP has a budget of RMB 337 billion (over US$ 40 billion) (Xu *et al*. 2004). From 1999-2008 the Chinese central government has invested RMB 191.8 billion (~US$ 28.8 billion) in the implementation of GGP (Lü *et al*. 2012).

Early outcomes and impacts of GGP

In spite of the relatively recent introduction of GGD in the Loess Plateau, several beneficial impacts have been observed. According to Chang *et al*. (2011), the total area of land use conversion in Loess Plateau, from sloping farmland to grassland, shrubs or forest, has already amounted to 2 million ha and has benefitted 2.5 million households (World Bank, 2007). Between 2000 and 2008 croplands decreased by 10.8%, while forest and grassland areas increased by 4.9% and 6.6%, respectively (Lü *et al*. 2012). This has helped reduce soil erosion losses. For example, Li *et al*. (2010) studied the soil erosion dynamics in the Zuli River basin in the Loess Plateau and found that the increased vegetation cover has reduced soil erosion by approximately 26%. Such reduced erosion and runoff has resulted in a lower water yield across the region (Lü *et al*. 2012).

Shi & Wang (2011) also found that the farming households in Mizhi had increased their net income after GGP enrollment with the higher income being mainly explained by increased off-farm employment through migration away from the farm after enrollment. Despite a reduction in farmland acreage, studies by Lü *et al*. (2012) and Shi & Wang (2011) report increased average grain productivity upon GGP implementation. However, the increase in average grain yields can largely be explained by the fact that it is marginal and low-yielding lands that are converted to non-agricultural use (Shi & Wang 2011).

Shi & Wang (2011) studied the ecological impacts of GGP in the county of Mizhi in the Loess Plateau and found a 58% higher content of soil organic matter on farmland converted to forest or grassland compared to non-converted farmlands. Chang *et al*. (2011) estimates the total soil organic carbon sequestration potential of GGP across the entire Loess Plateau to be 0.712 million tonnes (Mt) C/year. Net carbon sequestration was also estimated from vegetation and soil carbon change after re-vegetation was initiated in 2000 (Lü *et al*. 2012). Their findings suggest that the ecological rehabilitation efforts have had significant positive impacts on carbon sequestration, with carbon levels in soils and rehabilitated vegetation found to be 11.54 and 23.76 Mt C, respectively.

Lessons Learned

Whilst the use of 'slope steepness' of plots as the main inclusion criterion has the advantage of being a simple and straightforward method, Gauvin *et al*. (2010) argue that selecting plots based on environmental criteria only may lead to a neglect of the secondary GGP objective, that of poverty alleviation. However, despite this and some program weakness, i.e. the 'quasi-voluntary' nature and some cases of inadequate payments, the GGP has had positive poverty alleviation effects through elevating the participants' non-cropping income and asset base. Furthermore, the program's relatively high level of compensation is attractive to the rural dwellers and many local governments see the program as an opportunity to promote the transformation of the county's local economic structure (Uchida *et al*. 2007). In support of this observation, Lü *et al*. (2012) argue that the significance of GGP's direct financial compensations is only minor compared to the indirect effects of a 'socioeconomic transition from a food production-based rural community to a more active and profitable labor migration dominated rural economy'.

From a climate perspective it is interesting to note the robust climate trend analysis of historical weather data from 85 weather recording stations over a 57 year period by Lu *et al*. (2012), but it is disappointing to note that within this very large environmental and well-documented initiative, few field-based studies on above and below ground carbon sequestration appear to have been done.

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5.14. Herbicide-Tolerant Canola in Canada

Background information

Genetically modified (GM) crops have substantial potential to reduce agriculture's contribution to global GHG emissions for two reasons. Firstly, GM crops contribute to a reduction in fuel use due to less-frequent herbicide or insecticide applications and a reduction in the energy used in soil cultivation. Secondly, the use of no-till and reduced-till farming systems increases the amount of organic carbon in the form of crop residue that is sequestered in the soil, thus reducing carbon dioxide emissions to the environment (Brookes & Barfoot, 2005). In this case study, we examine the impacts of the adoption of HT-Canola in Canada.

Herbicide-tolerant (HT) canola (*brassica napus*) was introduced in Canada in 1995 via an 'identity preserved production scheme.' Two years later, unrestricted commercial production began (Gusta *et al*. 2011). Currently three types of HT canola are available on the market – two genetically modified (Liberty Link™ and Roundup Ready™) and one developed by mutagenesis (Clearfield®). Spraying with broad-spectrum herbicides directly on the crop is possible for all three HT canola varieties which has facilitated the widespread adoption of conservation tillage (or reduced tillage) practices among HT canola farmers in Canada (Beckie *et al*. 2011). Currently most canola in Canada is grown on the prairie of the Northern Great Plains regions of western Canada.

Since its introduction, the adoption of HT canola has been rapid, rising from 26% of the total canola area in 1997, the year of its introduction, to 78% by 2002 and 95% by 2007 corresponding to an area of 6 million ha (Smyth *et al*. 2011).

Outcomes and impacts of HT Canola

A survey examining the economic benefits of the genetically modified HT canola varieties Liberty Link™ and Roundup Ready™ in Canada by Gusta *et al*. (2011) found that from 2005-07, the direct and indirect benefits from this technology generated an annual additional CAD$ 1.063- $1.192 billion, attributed to both lower input costs and higher yields resulting from improved weed control.

Smyth *et al*. (2011) assessed the environmental impacts of HT canola in Canada. They found that from 2005-07 the total number of chemical applications had decreased on HT canola farmland, equivalent to nearly 1.3 million kg active ingredients herbicide annually. They also found declines in tillage passes on HT canola farmland during the period, leading to improved moisture conservation and decreased soil erosion with nearly two thirds of the HT canola producers in the survey using either zero-tillage or minimum tillage as the preferred form of weed management. They estimated that "1 million tonnes of carbon is either sequestered or no longer released under land management facilitated by HT canola production, as compared to 1995." They note that the increased soil organic matter associated with reduced-tillage leads to increased soil moisture levels, especially vital for agriculture in arid lands such as the prairies. The humus build-up is improving erodible land, leading to better soil structure.

Brookes & Barfoot (2005) compared the global impact of GM crops from 1996 to 2004. In Canada, they estimated that use of HT canola in Canada had led to 94 million kg CO_2e savings due to reduced fuel usage and a reduction in CO_2e of 906 million kg through soil carbon sequestration resulting from reduced tillage.

Lessons Learned

According to Beckie *et al*. (2011), the near 100% adoption of HT canola in Canada within ten years was driven by the clear benefits of the technology; easier and improved weed management, higher yields, and better seed quality with less weed seeds and higher net returns. Importantly, the convenience of HT canola management also meets the needs of large-scale agricultural producers and in addition, the adoption of HT canola has not restricted the market access; the Canadian export of canola products has not declined while the area under HT canola has increased (Beckie *et al*. 2011).

Concerns related to the introduction of HT traits into related wild species of canola, potentially creating a pervasive and uncontrollable weed problem, is according to the survey by Gusta *et al*. (2011), not an issue for the Canadian HT canola farmers. The vast majority of the respondents (94%) experienced improved or equal weed management.

From a climate perspective, GM crops have had a substantial impact on GHG emissions. Brookes and Barfoot (2012) studied the global impact of GM Soybean (USA, Argentina, Brazil, Bolivia), GM Canola (Canada), IR Cotton (global) and IR corn (Brazil). They found that, in 2010, a total of 17,634 million kg of carbon dioxide were sequestered, equivalent to taking 8.6 million 'average family cars' off the road for a year.

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5.15. The Drought Tolerant Maize for Africa Project

Background information

For over 300 million people in sub-Saharan Africa, maize (*Zea mays*) is a vital staple food crop with the vast majority being grown under rain-fed conditions. Drought tolerant varieties are therefore a crucial component in the battle against food insecurity in Africa (CIMMYT 2012a). According to CGIAR (2009) drought reduces maize yield globally by 15% every year, resulting in losses of more than 20 million tonnes of grain. Such droughts can have catastrophic effects. For instance, in 2011, more than 12.5 million people suffered from the effects of drought and resulting famines in the Horn of Africa (CIMMYT 2012a). The frequency of drought incidence is projected to increase as a result of climate change. Easterling *et al*. (2007) note that 'yields of grains and other crops could decrease substantially across the African continent because of increased frequency of drought …. Some crops (e.g. maize) could be discontinued in some areas.'

In response to the prevalence of current droughts and the projected increase in their frequency, the Drought Tolerant Maize for Africa (DTMA) Project was launched in 2006, coordinated by the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) (CIMMYT NA). DTMA is comprised of a broad partnership between nationally funded research organizations, NGOs, seed companies, certification agencies, and farmer groups in 13 countries in East, West and Southern Africa. Employing conventional breeding methods, project scientists are testing and selecting drought tolerant maize varieties from across the world. By combining other favorable traits such as high yield potential, good cooking qualities, and resistance to regionally important diseases, they have accelerated the development of new maize varieties with significantly improved drought tolerance (CIMMYT 2012b).

The DTMA project also coordinates capacity-building activities for all stakeholders (from farmer groups to maize breeders to extension workers) to guarantee that farmers obtain the highest possible gain of both products and services that the project providers (CIMMYT NA).

Objectives

The project aims to develop and disseminate drought tolerant, high-yielding, locally-adapted maize (CIMMYT 2012b). Project goals by 2016 are fourfold, namely: (i) Development of drought tolerant maize providing a 1 ton/ha yield increase under drought stress conditions, (ii) Increasing the average productivity of maize under smallholder farmer conditions by 20–30% on adopting farms, (iii) Reaching 30-40 million people in sub-Saharan Africa, and (iv) Adding US$ 160–200 million of grain in drought affected areas (CIMMYT & IITA 2007; La Rovere *et al*. 2010).

Funding

Funds are provided by the Bill & Melinda Gates Foundation, the Howard G. Buffett Foundation, USAID, and the UK Department for International Development (CIMMYT NA).

Early outcomes and potential impacts

More than 34 new drought tolerant maize varieties have been developed and deployed to approximately 2 million smallholders across 13 African countries (CIMMYT 2012a). According to CIMMYT (2012b) these drought tolerant varieties are giving farmers higher yield, improved food security, and increased incomes, and the project has already made good progress in the achievement of its second goal of increasing maize productivity under smallholder farmer conditions by 20-30%.

The DTMA project is, according to CIMMYT (2012a), providing an insurance against major climate and disease risks currently facing maize farming. The disseminated varieties not only provide a decent harvest under reduced rainfall, but match or exceed the yields of popular commercial varieties under good rains. An *ex-ante* assessment study by La Rovere *et al*. (2010) on the potential impacts of the DTMA project indicates that (with optimistic adoption rates and yield increase of 10-34% over non-drought tolerant varieties) the DTMA project could lead to a cumulative economic benefit of nearly US$ 0.9 billion to farmers and consumers. In addition they estimate that drought tolerant maize could assist more than 4 million people in escaping poverty while improving the livelihood of many millions more.

Lessons learned

Tambo and Abdoulaye (2012) studied the determinants of smallholder adoption of drought tolerant maize in Nigeria. They found that, over and above drought tolerance *per se*, several key factors enhanced the adoption of drought tolerant maize by farmers, namely easy access to markets, level of farmer education, household wealth, and repeated visits by extension staff. The possible inference of this is that poorer and more remote farming communities may face constraints in adopting DTMA maize varieties.

Whilst it would seem clear that DTMA varieties will enhance many millions of farmers' ability to cope with the current risks of drought, it is not so clear that they will necessarily be well adapted to droughts occurring in a warming world. Burke *et al*. (2009) conclude that "we find that for three of Africa's primary cereal crops – maize, millet, and sorghum – expected changes in growing season temperature are considerable and dwarf changes projected for precipitation." This is important since the estimated negative maize yield impact in 75% of maize-growing areas across sub-Saharan Africa is calculated to be at least 20% for every 1°C. increase in temperature (Lobell *et al*. 2011). High temperature tolerance and modified disease resistance, due to possible change in plant diseases dynamics (Garret *et al*. 2011), may well prove to be equally critical as drought tolerance in adapting to tomorrow's maize growing environments in Africa.

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5.16. Contour Stone Bunds: Conserving soil and water in the Sahel

Background information

High intensity rainfall coupled with inherently low fertility and crust-prone soils are characteristic of large areas of the Sahel and result in widespread rainfall runoff and soil erosion (Sivakumar and Wallace 1991; Roose 1994; Breman *et al*. 2001). Indeed, crop water deficits are often more a function of water lost through run-off than rainfall shortages *per se* (Mando 1997). To address this, farmers, extension workers, and governments have placed priority on a range of measures for run-off and soil erosion control (Mando *et al*. 2001).

One such measure, the use of stone bunds built on natural contour lines, has been promoted and supported for more than 25 years and has proven to be both an effective and durable innovation which is now widely used by farmers in the Sahel (Zougmoré *et al*. 2000; Barry *et al*. 2008). Built with quarry rock or stones, the stone bunds are constructed in lines along the natural contours of the land after 10-15 cm of the soil has been removed from the line where they are to be built. They are built to a height of 20-30cm and spaced 20 to 50m apart depending on the slope of the land. By slowing the lateral flow of water, this technique is particularly efficient in reducing runoff and improving rainwater infiltration (Zougmoré *et al*. 2000) and, as a result, also reduces fine sediment transport by runoff (Mando *et al*. 2001).

The best results are often achieved when contour stone bunds are used in combination with biological measures such as the planting of grass, trees and hedges on the contour lines (Errath *et al*. 1989). Owing to widespread soil nutrient deficiency, the complimentary use of organic mulch or fertilizer on crops is often required to achieve associated improvements in crop yields (Zougmoré *et al*. 2004). In addition, where soils are particularly degraded and liable to surface crusting and runoff, farmers often combine contour stone bunds with '*zai*' planting pits, which are 10-20 cm deep and act as micro-catchments.

Such rainfall runoff control measures are important in the context of CSA. Changes in rainfall patterns in the Sahel due to global warming are uncertain with respect to projected rainfall amounts increasing or decreasing (IPCC 2007). However, stones bunds are likely to prove beneficial under both wetter and drier scenarios. In years of above average rainfall, they are effective in protecting the soil against excessive erosion, although water logging in such years may present a problem. In drier years they still contribute to effective rainwater harvesting and an increase in crop-available soil water. Such an increase in available water in the soil profile will help to mitigate the predicted decrease in the Length of Growing Period (LGP) in the Sahel due to global warming (Thornton *et al*. 2006). In addition, IPCC (2007) projects that heavy rainfall events in the Sahel are likely to increase in frequency and intensity. In that respect, durable and effective soil erosion control structures will assume even greater importance and constitute an important adaptation measure.

Outcomes and impacts

The use of contour stone bunds has been widely promoted across the Sahel by both government and non-government programs since the 1980's and a great deal of technical and logistical support has been provided for the correct laying of contour bunds and the quarrying, collection and transportation of stones (Rochette 1989). Such support has been essential as the innovation is both labor-intensive and costly. For example, in Burkina Faso, between 1987 and 2006, the German funded PATECORE project supported the reclamation of over 100,000 ha of degraded land with approximately 30,000 km of contour stones bunds. However, this required the quarrying and transport of 2.5 million cubic meters of stones at a net cost of US$ 200/ha and between 100-150 person days of unpaid labor per hectare (Landolt 2011). Whilst data for the region-wide scale of adoption across the Sahel appears scarce, Reij *et al*. (2009) estimate that between 200,000 and 300,000 hectares of degraded land has been rehabilitated in the Sahel through the use of contour stone bunds, very often combined with the use of '*zai*' planting pits.

Although it is clear that contour stone bunds are effective in reducing soil erosion and increasing crop-available water (Zougmoré *et al*. 2003), corresponding increases in crop yields, hence greater food security and/or income generated will depend on the nutrient status of the soil. Fifteen years after the bunds were established, Nill (2005) reported an increase in millet yields of up to 40% without any additional nutrient supply in the Project Agro-Sylvo Pastoral (PASP) in Niger, and a similar response was observed in Burkina Faso (PASP, 2003). In contrast, from a study at Saria Station in Burkina Faso, Zougmoré *et al*. (2010) concluded that "without nutrient inputs, soil water conservation (SWC) measures hardly affected sorghum yields, and without SWC, fertilizer inputs also had little effect. However, combining SWC and nutrient management caused an increase in sorghum yield of up to 142%."

Further support for the need to combine water runoff management with soil nutrient management comes from observations on the impact of the PATECORE project in Burkina Faso. Landolt (2011) identified a range of both poverty and hunger reduction benefits (increased yields, introduction of cash crops, greater food security and income) and environmental benefits (raised water tables, increased vegetation cover, increased stock of trees, reduced pressure on nearby savannahs, increased species diversity) when contour stone bunds were constructed and organic fertilizer was used.

Lessons learned

Contour stone bunds have proven to be both effective and durable with respect to controlling rainfall run-off and soil erosion, but there are high 'up front' costs associated with their installation. These include the cost of quarrying and transporting the stones to the field, the need to provide basic field equipment such as water levelers to identify contour lines, picks and shovels. As a result of these costs, such stone bunds are seldom installed without support from government projects, National Extension Services or NGO's (Zougmoré *et al*. 2000). However, even when such support is available, the farmers' commitment to provide the labor that is required largely depends on whether they are allowed to choose the sites to be improved in their area. Forcing them to begin the improvement work 'upstream', as is usually recommended in the development of watersheds, has often proved counterproductive. Most communities prefer to improve individual cultivated plots first in order to achieve an immediate effect on crop production and leave the treatment of the upstream forest or rangeland areas as a second step.

Contour stones bunds usually act as the key innovation upon which a more integrated approach is built. This can include the additional contour planting of the stone bunds with *Andropogon gayanus* or shrubs (Errath *et al*. 1989), the use of *zai* pits on the adjacent crop land (Reij *et al*. 2009) and often the addition of compost or mineral fertilizer (Zougmoré *et al*. 2010). Each of these components will result in additional or interactive benefits with respect to reduced run-off and erosion as well as increased crop yield. Because of this, it is difficult to quantify the biophysical and socio-economic benefits of the contour stone bunds themselves. In addition, in spite of their widespread adoption and continued promotion, information available on the extent of their adoption on a regional basis is still scarce.

Increased vegetative cover (trees, shrubs, grasses) on land where contour stone bunds have been constructed has been observed by many (e.g. Landolt 2011) and greater carbon sequestration is claimed. However, we could not find references to actual on-the-ground measurement to quantify this claim.

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