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Managing climate risk using climate-smart agriculture

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The problem

Climate change alters the agriculture production conditions and food security of developing countries, increasing the frequency and depth of risk to agricultural production and incomes. Policy-makers need assistance in identifying risk management options in the agricultural sector that allow them to effectively respond to the climate risks they face, while maintaining and enhancing agricultural policy objectives. Climate-smart agricultural (CSA) approach was developed to provide this assistance and this brief highlights some of the key findings related to risk management from CSA case studies.

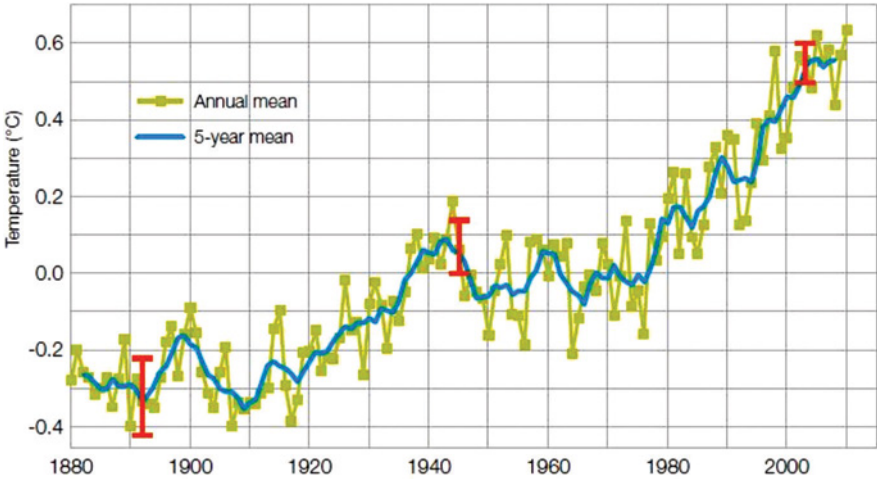
Key messages

- The exposure to climate risks vary considerably within countries and production systems and thus effective adaptation options vary as well.
- Some farmers are already effectively adapting to climate change, but many are not. Agricultural extension and climate information services play an important role in effective adaptation.
- It is important to manage both downside and upside risk and thus combining risk management instruments (e.g. insurance with diversification) will be necessary.
- Social protection programs are already an important means of managing climate risks, but their effectiveness can be improved by integrating climate risk vulnerability in targeting criteria.

1. Climate change and food security

There is a growing consensus in the scientific literature that the earth is warming due to anthropogenic increases in greenhouse gas emissions into the atmosphere (IPCC, 2014) (see Fig. 1). There is considerable reason to be concerned about the effects on food security. We have seen several periods of rapid food and cereal price increases following extreme climatic events in key producing regions, indicating a sensitivity of current markets to the changing climatic conditions. Studies have also documented a large decrease in crop yields resulting from extreme daytime temperatures around 30 °C (IPCC, 2014). Several other studies report that temperature trends are important for determining both past and future impacts of climate change on crop yields at sub-continental to global scales. Together with temperature increases, climate change is expected to result in increasingly unpredictable and variable rainfall (both in amount and timing), changing seasonal patterns and more frequent occurrence of extreme weather events. The IPCC (2014) report also points out that changes in climate and CO₂ concentrations will enhance the distribution and increase the competitiveness of agronomically important and invasive weeds, which is generally not accounted for in current projections of climate change impacts on agricultural productivity, but which could be quite significant. Considering these effects, it is generally recognized that climate change has very significant implications for smallholder agriculture.

Figure 1 - Global land/ocean temperature index



Source: NASA

As a result of climate change, some cultivated areas may become unsuitable for cropping and some tropical grassland may become more and more arid. In sub-Saharan Africa alone, projections predict a loss of 10-20 million hectares of land available for double cropping and 5-10 million hectares for triple cropping as a result of climate change (FAO, 2015; Fischer *et al.*, 2005; Schmidhuber and Tubiello, 2007). At the regional level, the biggest losses in cropland due to climate change are likely to be in Africa. People exposed to the most severe climate-related hazards are often those least able to cope with the associated impacts, due to their limited adaptive capacity. This in turn poses multiple threats to economic growth, wider poverty reduction, and the achievement of the Sustainable Development Goals (SDGs).

Climate change threatens agriculture and food production in complex ways. It influences food production directly through changes in agro-ecological conditions and indirectly by affecting the growth and the distribution of incomes, and thus the demand for agricultural produce (Schmidhuber and Tubiello, 2007). According to the IPCC (2014) report all aspects of food security are potentially hit by climate change, including food access, utilization, and price stability. In order to be able to cope against the negative impact of climate change, farmers need *ex-ante* and *ex-post* strategies for managing climate risks that enable them to enhance their livelihoods, e.g. increase their resilience. Therefore, the state of knowledge and experience to date implies that we need to think of different strategies to manage climate risk at the farm level (McCarthy *et al.*, 2016).

2. Agricultural risk management in Africa

Almost three quarter of economically active rural populations in Africa are smallholder farmers, making them important players in national agricultural development. Since the livelihoods of these farmers are largely based on agriculture, agricultural development that contributes to increasing the productivity, profitability and sustainability of smallholder farming is critical for reducing poverty and improving food security and nutrition. Agriculture in Africa, however, is an inherently risky business. Agriculture in Africa

is increasingly exposed to a variety of risks and uncertainties, including market risk; production risks – climate variability such as drought and floods – pest and disease outbreaks and windstorms; and institutional risks (Antonaci *et al.*, 2012). Drought, floods and wide swings in fertilizer prices and world food prices translate into high variability in domestic production and staple food prices. In the absence of risk management institutions, farmers adopt less risky and less profitable land uses that lower overall productivity. Available studies suggest that farm incomes would be as much as 30 percent higher than current levels if farmers had the option of effectively mitigating risks (Minot, 2010). Given the high costs these risks impose – on national incomes, vulnerable household welfare and political stability – managing these risks remains central to achieving rapid agricultural productivity and growth.

Government strategies for managing agricultural risks at the household or community level have taken different forms in different countries, but are generally classified into three: (i) Mitigation/Adaptation – activities designed to reduce the likelihood of an adverse event or reduce the severity of actual losses. Risk mitigation options are numerous and varied (e.g., irrigation, use of resistant seeds, improved early warning systems, and adoption of better agronomic practices); (ii) risk transfer – this entails the transfer of risk to a willing party, for a fee or premium. Commercial insurance (e.g. weather index insurance) and hedging are well-known forms of risk transfer; and (iii) risk coping – this involves improving resilience of households to cope with events, through ex-ante and ex-post preparation. Examples include social safety net programmes, buffer funds, savings, strategic reserves, etc. Unlike in other parts of the world, most farmers in Africa have no access to government or market-based risk management tools and, when they do, government programmes or private sector initiatives to manage price and production instability are often insufficient.

Policy makers, practitioners, and food policy researchers have long debated means of managing these risks. The resulting lively debates have focused on finding the right mix of short term interventions for managing risk while the countries find ways to solve underlying causes. Agricultural risks result from underlying agro-ecological, infrastructural, and institutional bottlenecks. These bottlenecks are the ultimate source of agricultural risks and hence, long-run risk management policies need to focus on addressing these problems at source. These efforts will require substantial increases in long-term public investment in agriculture. Yet in recent years, public investments in agriculture have averaged about 4–6 percent for Africa, and only a handful of countries have reached or exceeded the CAADP target of 10 percent (Minot, 2010). As a result, public investments in building basic market fundamentals (e.g., rural roads, rural electricity, telecommunications, etc.) continue to remain low. Investments in rural roads, R&D for drought tolerant varieties, crop diversification and irrigation will need to be stepped up in order to reduce or eliminate sources of production and price risks. At the same time government should also invest in short-term traditional (e.g., government let grain reserve) and modern instruments (e.g. weather based insurance, agricultural commodity exchanges, warehouse receipt systems etc.) for managing agricultural risk.

The purpose of all these different risk management strategies is to strengthen the responsiveness to shocks of rural producers, allowing them to update farming practices and to invest in new technologies and know-how, boosting productivity, income, economic growth and wealth. The risk management and resilience building approaches, which need to be adapted to the specific local context, are based

on a mapping of the various risks affecting both farmers and households' access to food, identifying the appropriate risk-hedging instruments and institutions, and providing adequate training to national experts, rural producers and institutions to integrate agricultural risk management (from design to implementation). In this brief, we try to provide insight on how climate-smart agricultural (CSA) approach can be combined with market and institutional risk management tools and policy instruments to manage some of agricultural risk esp. climate risk at farm level.


3. Managing climate risk through climate-smart agriculture

Since the effects of climate change are already being felt, incorporating adaptation into agricultural policies, plans and investments is needed to maintain and enhance the benefits obtained from agriculture. Risk management strategies have a prominent role to play in adaptation, ranging from increasing resilience of agro-ecosystems through better management of ecosystem services, increasing resilience of livelihoods through social protections policies to disaster risk response.

The question facing communities, planners and policy-makers is what types of risk management programs are likely to be most effective for the type of climate risk exposure they face, and the level of vulnerability of their agricultural production systems and population? Are there trade-offs between risk management and economic growth? How can the risk management needed for adaptation be integrated into agricultural policies and investments? Climate smart agriculture is an approach developed to help answer these questions.

The meaning and definition of the term CSA has evolved over the past years, in particular in relation to the concept of sustainable agriculture (see Box 1).

Box 1 - The evolving concept of CSA

CSA seeks to support countries in securing the necessary policies, as well as the technical and financial conditions, to enable them to i) sustainably increase agricultural productivity and incomes; ii) build both the resilience and the capacity of agricultural and food systems to adapt to climate change, and iii) seek opportunities to reduce and remove GHGs in order to meet their national food security and development goals. CSA is site-specific and takes into consideration the synergies and trade-offs between multiple objectives that are set in diverse social, economic, and environmental contexts wherever applied. CSA builds upon sustainable agriculture approaches, using principles of ecosystem and sustainable land/water management and landscape analysis, as well as assessments of resource and energy use in agricultural and food systems. 

- ▶ Innovative financing mechanisms that link and blend climate and agricultural finance from public and private sector are critical to the implementation of CSA, as are the integration and coordination of relevant policy instruments. The adoption of CSA practices at scale will require appropriate institutional and governance mechanisms to facilitate the dissemination of information and ensure broad participation.

The methodology FAO has developed with its partner countries for the CSA approach includes development of an evidence base to inform agricultural policy and investment planning, cross-sector policy dialogues and linking climate finance to agricultural investments.

The evidence base should be designed to highlight climate change impacts on specific agricultural systems and producers over the near and medium term future and identify potential options for effectively adapting to these changes while maintaining or enhancing processes of sustainable agricultural development. Estimating the degree to which these options could also reduce greenhouse gas emissions compared to a baseline, or business as usual growth path and the potential costs of achieving these reductions are yet another fundamental component. The final piece of the evidence base is focussed on identifying institutional and financing needs to actual implement the priority actions. Both analytical work and stakeholder consultations are needed in building the evidence base, and the process needs to be designed to recognize various points of view as well as considerable uncertainty since there's still much unknown about how climate change will actually unfold.

Cross-sectoral policy dialogues form an important part of the CSA methodology, to enhance coordination between agricultural, climate change, social protection, food security – and other relevant policies at local, national and international levels. These can take the form of dedicated workshops to discuss emerging policies, or presentations and discussions amongst standing committees or public sector bodies involved in policy formation. Improving the links between climate finance and agricultural investments is needed to both increase the flow of funds and to better target them to meet priority objectives. There are a range of climate finance sources, from carbon markets to public sector funds such as the Global Environment Fund (GEF) and the Green Climate Fund (GCF). Linking climate finance to agricultural investments requires some capacity to measure, report and verify that actions are indeed generating adaptation and mitigation benefits. The CSA evidence base can provide much of the information needed for making this link.

The CSA approach is designed to focus on immediate actions that can be taken to support a transformative process that would unfold over time. The CSA approach seeks to answer the question "what steps can be taken now to move towards a more sustainable future in agriculture under climate change", as opposed to focusing on the features of some future ideal system of sustainability. The focus of CSA, and more generally of FAO work on sustainable food and agricultural systems, is on building transition strategies that are tailored to existing agro-ecological, socio-economic and policy conditions, looking for key opportunities for opening a transition process, while taking constraints explicitly into account.

4. How does the CSA approach address the issue of risk management? Results from Malawi and Zambia

4.1. *Historical and near future risks associated with climate change*

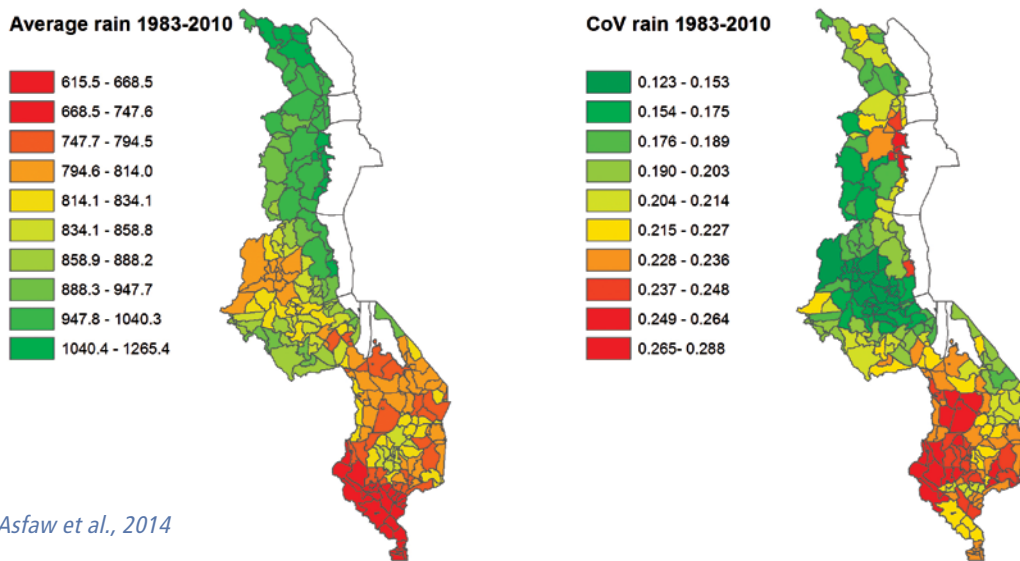
An important part of building the CSA evidence base involves assessment of current and near future risks associated with climate change. This was done by looking at historical and recent changes in relevant climate/weather variables at sub-national level as a first step in identifying the site-specific impacts of climate change on agriculture. There is an emerging economic literature on weather variables/shocks and their implications for a wide set of economic outcomes ranging from economic growth, to migration and agriculture. For Malawi and Zambia, we recognize the importance of these linkages and exploits the recent improvements in data availability to create a novel set of variables to characterize local level weather variations and shocks these countries. Rainfall data from the Africa Rainfall Climatology version 2 (ARC2) of the National Oceanic and Atmospheric Administration's Climate Prediction Centre (NOAA-CPC) since 1983-2012 are used to create rainfall related variables.¹ Temperature data since 1989 are obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF).² We use actual climate realizations to control for their effects on yields while we use long-term historical data on rainfall patterns and temperatures to capture farmer expectations about climate at the beginning of the season. The long-term historical variables include long-term average rainfall, the coefficient of variation of rainfall, the average delay in the onset of the rainy season, long-term maximum growing season temperature, and the coefficient of variation in maximum temperature. The variables are measured on a decadal basis and linked to the sampling distribution of the Integrated Household Survey (IHS), using geo-referenced coordinates for the enumeration areas of the IHS survey. This allows for an analysis of the impacts of climate variables on household agricultural practices and yields.

Figures 2 show the geographic distribution of long-term average and coefficient of variation of rainfall and illustrates that the Northern provinces experience relatively higher levels of rainfall, on average, compared to the Southern and Central provinces. While across the three regions there are fairly distinct rain and climate regimes, the same is not the case for the coefficient of variation of rainfall. As the figure shows, while the Northern region has more favourable rainfall conditions, farmers are exposed to significant variability within the region. Farmers in the Southern provinces are particularly vulnerable to weather conditions given the lower amount of average rainfall combined with the highest rainfall variability. Finally, in the Central region long-term average rainfall is higher than in the South but lower than in the North, although the Central region reports the lowest rainfall variability.

¹ ARC2 data are based on the latest estimation techniques on a daily basis and have a spatial resolution of 0.1 degrees (~10 km). See http://www.cpc.ncep.noaa.gov/products/fews/AFR_CLIM/AMS_ARC2a.pdf for more information on ARC2 algorithms.

² ECMWF data are surface temperature measurements at 10 day intervals (i.e. dekad). See <http://www.ecmwf.int/en/forecasts/datasets/era-interim-dataset-january-1979-present> for more information.

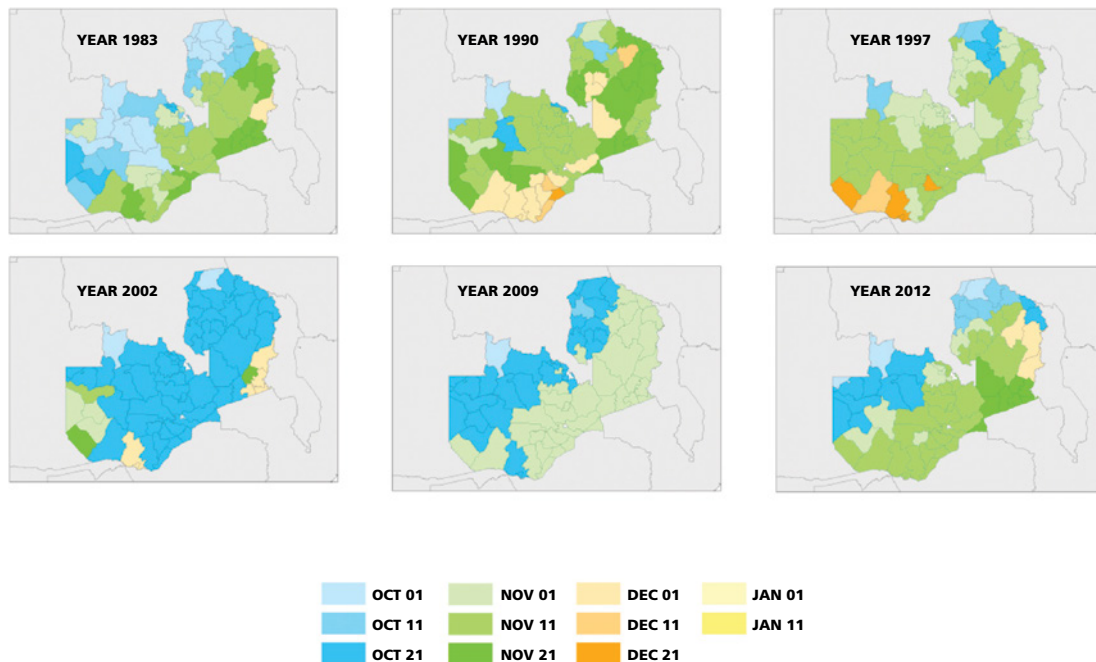
Figure 2 - Total amount of rainfall and coefficient of variation (CoV) of rainfall in Malawi



Source: Asfaw et al., 2014

Figure 3 shows the geographic distribution of delayed onset of rainfall in Zambia. It shows that the onset of rainfall over the years to be unpredictable which has huge implications for farm-level decision for agricultural activities. Farmers' expectations about the onset of rainfall matter enormously for their decision on when to plant crops and access the necessary inputs. The socio-economic impacts of such climatic variability on smallholder farmers are a function of their adaptive capacity and of their coping strategies.

Figure 3 - Delayed onset of rainfall in Zambia



Source: Arslan et al., 2013

Another very important element is assessing the near term projections of climate change predictions at each locality by using of down-scaled global climate models (GCM). GCM can be combined with crop models to assess the projected impacts on crop production. The point of this exercise is to check whether recent past information that is used in the statistical analyses explained above is actually a good guide to what we can expect in the near future in terms of climate and crop production patterns. For Malawi and Zambia, the projections from existing GCMs at local scale are used to assess the potential impacts of climate change on local climate indicators that are important for crop production, productivity and its stability over time.

4.2 Resilience of agricultural systems to climate shocks

The next step in the development of the CSA evidence base was to assess how well various practices performed in terms of resilience to climate shocks.³ One of the most important ways of building resilience in agricultural ecosystems is improving soil quality and in fact, in Zambia we did find that farmers in areas of high rainfall variability were more likely to adopt minimum soil disturbance techniques that are contribute to building soil quality. Not surprisingly, the presence of extension services in a village has a strong and positive effect on the likelihood of farmers adopting practices that contribute to resilience. We also find maize yields to be higher for farmers using legume intercropping while farmers practicing minimum soil disturbance and crop rotation do not enjoy higher maize yields when compared with others. On the other hand farmers using inorganic fertilizer and improved maize seeds tend to have higher maize yields compared to farmers who are not using (see Tab. 1). We also find that climate variability and shocks change the impacts of different practices on maize yield. For instance, farmers practicing legume intercropping tend to enjoy higher maize yield even though they are residing in an area of higher climatic shocks. However, farmers using inorganic fertilizer and improved seeds tend to have lower yields under false rainfall onsets.

Similar story emerges from Malawi. We find that climate change related effects are an important determinant of the practices farmers select, although the effect are quite heterogeneous across agro-ecologies and thus the distribution of practices selected. Farmers in area of higher climate variability tend to use more sustainable land management (SLM) measures, but use lower levels of other inputs such as inorganic fertilizer. We also find that farm practice selection is an important means of adaptation that farmers are already practicing as demonstrated by positive yield effects across a range of practices, exposure and sensitivity to climate change. Farmers using modern inputs and SLM practices tend to have higher maize yields compared to non-adopters. However, the effectiveness of practices varies by exposure to climatic risk with greater benefits from the SLM practices in areas of higher exposure and sensitivity; whereas improved seed and fertilizer perform better in areas of lower risk exposure

³ For Malawi and Zambia, we uses both of these approaches as necessary. Using a nationally representative data from various sources, we created a set of variables to analyse both the determinants of adoption and productivity/food security and other resilience impacts of potential CSA activities. In Malawi, the World Bank's Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) are used, whereas in Zambia Rural Agricultural Livelihoods Surveys (RALS) from the Indaba Agricultural Policy Research Institute in collaboration with the Central Statistical Office are used to do the analyses. These data are then merged with the climate variables mentioned above to account for specific climatic/weather conditions at each level (village, commune or agro-ecological zone).

Table 1 - Impacts on crop yields under different climate effects: Zambia & Malawi

	Higher Yields	Lower Yields	Reduced probability of yield loss
Average climatic conditions	Legume intercropping Inorganic fertilizer Improved seed	Crop rotation	Inorganic fertilizer Improved seed Timely fertilizer access
Increased rainfall Variability	Crop rotation Timely fertilizer access	Inorganic fertilizer	Crop rotation
Delayed onset of rainfall	Improved seed Legume intercropping Timely fertilizer access	Inorganic fertilizer	Inorganic fertilizer
Increased seasonal temperature	Legume intercropping Timely fertilizer access	Improved seed	Legume intercropping Improved seed

Source: Arslan et al., 2015; Asfaw et al., 2014

4.3 Simulation of risk management strategies

For the purpose of operationalizing a CSA strategy within the framework of agricultural risk management, it is crucial to have a clear idea of the interaction between different kinds of risk management options. In Malawi, we conducted an analysis on how potential future climate change, by affecting the mean, variability, and covariance of weather events, affects the appropriateness of different risk management tools, such as crop insurance, diversification by farmers, adoption of CSA practices and the interaction between these elements.⁴ This is done by estimating production functions for different crops and yield variation functions, and then simulating the outcome of farmer decisions. Comparing outcomes under the more and less restrictive staple requirements (i.e., about 70% of the area is allocated to staple production (maize)), we see higher levels of diversification when the staple requirement is relaxed, but that greater diversification into a cash crop opens the farmer up to greater losses under climate change. These results suggest that farmers that are currently somewhat better off (and thus are less constrained by subsistence requirements to plant a staple crop) are able to accept higher levels of risk in order to obtain higher returns. While information regarding climate change (i.e. when the changes in weather conditions are anticipated) improves outcomes for all farmers under the climate change scenarios, the improvement is most dramatic for farmers with diversified crop portfolios. Thus, the implication is that the better-off farmers would most benefit from the climate information.

Since the insurance instrument we analyzed is triggered by rainfall level and not by realized losses, the effect on cropping and land management practices is minimal. This is important, in order to avoid insurance programs inhibiting adaptation. Diversification and adoption of resilience building land management practices differ from insurance in the way they affect a risk profile. Insurance will exclusively

⁴ The empirical application, which presents results for farmers in the tropical warm/semi-arid AEZ of Malawi, builds on the conceptual model by estimating production functions for different crops and yield variation functions, and then simulating the outcome of farmer decisions. We simulate the impacts of weather index insurance and extension under a range of climate change scenarios for two levels of staple requirements.

reduce downside risk (*i.e.*, the worst case scenario) whereas diversification and land management practices may reduce both downside and upside risk (*i.e.*, possible desirable outcome). Indeed the model simulations indicate that under scenarios of fairly pronounced climate change, farmers will switch to higher levels of diversification as the insurance payout amount increases. As insurance reduces downside risk, farmers have an incentive to invest in higher risk and higher returns activities. The importance of extension is confirmed by the simulations, indicating that more information on climatic conditions and their impact on yields does potentially drive different crop and land management practices. Importantly we see that farmer outcomes improve as they are provided with additional information, and that the value of information increases as realized weather conditions deviate further from baseline expectations (that is, under scenarios in which climate change is more extreme). These results also highlight how the value of information is higher for farmers that are less restricted in their planting choices, since they have a broader scope to adapt (Mullins *et al.*, 2016).

4.4. Role of social protection in managing climate risk

Social protection is generally recognized as a critical strategy for poverty alleviation. Social protection can take on a variety of forms, from cash transfers to school meals to public works. When targeted at the poorest and most vulnerable, these policies may be seen as social protection interventions in their own right. Policies promoting agricultural production, such as input subsidies, may also have a social protection function to the extent that they help reduce vulnerability of smallholder farm households to price volatility. Evidence coming from Latin America, and also emerging from Sub-Saharan Africa are showing clear impacts in terms of food security and human capital development as well as on enhancing the economic and productive capacity of even the poorest and most marginalized communities. Beyond poverty alleviation, the combination of social and economic impacts is also seen as contributing to strengthening resilience. The linkages between social safety-net and climate change adaptation strategies are critical. On the one hand, climate-related disasters such as droughts, floods can further exacerbate pre-existing economic and social vulnerabilities experienced by poor households. On the other, the poorest and most excluded are most likely to be hit hardest from repeated shocks and stresses and may be forced to resort to negative coping strategies that will affect their livelihoods, well-being and environmental stability, *i.e.*; selling of productive assets, reduce amount and quality of food intake, over-exploitation of lands and forest, among other.

By ensuring predictability and regularity, social protection instruments enable households to better manage risks and engage in more profitable livelihood and agricultural activities. When directed towards women, they are not only empowered, but households' welfare is also improved because of women's priorities for food and nutrition and their children's education and wellbeing. Poor households spend most of their income on food and there is broad evidence that social protection interventions improve household food security and child nutrition. Aside from direct income support, social protection programs have an important impact on agricultural investment decisions of rural households and thus have a longer term positive impact on food access. For example, the livelihoods

of most social protection beneficiaries in sub-Saharan Africa are predominantly based on subsistence agriculture and rural labour markets, and this will continue to prevail for the foreseeable future. Local labour markets often do not provide many opportunities for overcoming poverty and, as a result, poor households tend to resort to self-employment, whether in or outside agriculture. Moreover, most beneficiaries live in places where markets for credit, insurance, labour, goods and inputs are lacking or functioning poorly. In this context, when social protection is provided in a regular and predictable manner, it helps households to overcome credit constraints and better manage risks. This, in turn, helps induce more productive investments, improve access to markets and stimulate local economic activity and employment creation.

The risk management function of social protection programs clearly has an important role to play in the context of increasing risk exposure from climate change. However, the existing social protection programs rarely takes into account climate risk in its design and implementations. As poverty reduction instruments, the targeting of social safety-net interventions would tend to include mainly economic (wealth and income) related criteria. It is thus important to move from a system of narrow targeting criteria to a multidimensional approach which would include environmental risks and vulnerabilities. Overlaying maps of income poverty and food insecurity with vulnerability maps linked to climate change is a first step towards this.

To maximize the impact of social safety-net to manage climate risk, especially for predictable hazards, it is important to ensure effective linkage between social protection management and information systems (MIS) with early warning systems and ensure that the former are able to integrate additional beneficiaries, in the time of crises. Public works, including productive safety nets and other kind of public works can be designed in such a way as to contribute to meet increase household income, while at the same time engaging communities in climate smart agriculture and generating of 'green jobs' in areas such as waste management, reforestation and soil erosion prevention. Overlapping access to social safety-net and access to key financial services such as credit and weather insurance to reduce uncertainty and impacts of climate variability.

Box 2. How effective are social protection programs in mitigating climate risks: Insights from the Zambia Child Grant program.

The Zambia Child Grant Program (CGP) is Zambia's flagship social protection cash transfer programme. Implemented in 2010 by the Ministry of Community Development, Mother and Child Health (MCDMCH), the programme currently reaches 20 000 ultra-poor households with children under the age of 5 in three districts (Shangombo, Kalabo and Kaputa). The CGP transfers ZMK 60 per month to each household, which on average in 2010 represented 28 percent of monthly expenditure.



► The question is how effective the program has been in reducing the vulnerability of households to food insecurity for households exposed to relatively high levels of climate risk. To answer that, an analysis of the program impacts was conducted, using information from 2010 and 2012 household surveys, together with data on historical rainfall patterns obtained from Africa Rainfall Climatology v.2 (ARC2). The analysis shows that overall, households in areas that experienced lower than average rainfall had lower levels of daily caloric intake as well as food and non-food expenditures, and this effect was most pronounced for the poorest households in the sample. The households that participated in the Child Grant Program had much lower negative effects of the weather shock, and it was the poorest households that had the greatest gains. This indicates the potential of social protection to support food access for households exposed to climate risk. However, the analysis also indicates that while participation in the CGP is beneficial in mitigating negative effects of climate shocks on food security, it is not sufficient to fully overcome these effects. Thus it is important to ensure that that social protection programs are well aligned with other forms of climate risk management, including disaster risk reduction activities ((Asfaw *et al.*, 2016).

5. Designing effective CSA strategy at country level

Designing a CSA strategy at country level requires the coordination of activities that fall under a number of stakeholders, such as (i) adaptation by farmers (private sector); (ii) the provision of credit (by the financial sector and possibly government) for investment in climate-smart activities; (iii) the definition of coherent policies for food security, adaptation to climate change, and the provision of environmental services (government); and (iv) the generation and dissemination of information on climate variability and its economic and social implications (research and extension).

CSA activities can range over a very broad spectrum, depending on the relative importance of its three pillars – food security, adaptation, and GHG mitigation – in a given country. Any country developing an agricultural strategy in the context of a changing climate will have to first assess what CSA practices are relevant given existing and projected climate variability, the current production patterns and practices, and whether there is mitigation potential that might provide additional financing. Typically this initial screening of potentially relevant CSA practices will be driven by the vulnerability of staple crops and whether there are low cost GHG mitigation options that could be useful in financing activities focusing on food security and adaptation. Once potentially relevant CSA activities have been identified, baseline activities without CSA interventions by stakeholders will be defined, forming another part of the assessment process. This is relevant both for obtaining adaptation funds, based on potential vulnerability,

and for mitigation funds for which the baseline can serve as a reference level for accounting for emission reductions. Potential CSA options identified in the initial assessment screening will then be evaluated according to economic and social criteria in line with a country's food security and development objectives. In developing the initial assessment, it will also be useful to consider potential synergies and trade-offs relative to the baseline activities for those CSA practices that are thought to be relevant. Synergies will be important when preparing investment proposals, whereas trade-offs will matter when making the decision as to whether or not to adopt specific CSA activities given existing constraints.

An essential part of the process of developing a CSA strategy is to understand barriers to adoption of CSA practices. Some barriers may be due to trade-offs that CSA practices engender in terms of resource use (e.g. crop residue management competing with livestock forage or labour intensiveness of some practices). However, it can also be that farmers would like to adopt certain practices, but do not due to institutional barriers, financial bottlenecks, or a lack of access to input or output markets. Understanding what drives adoption or dis-adoption of CSA practices is an empirical question that needs to be answered to make informed choices on guiding policies and investments. With an appreciation of potentially relevant CSA practices, the barriers to their adoption, their implications for farmers' management of risk, and the benefits and costs of these different CSA practices, it is possible to combine this information to develop a CSA strategy that takes into consideration technical, institutional, and economic aspects. This will allow for a prioritization of CSA activities and create an enabling and coherent policy environment for agricultural development that takes climate change into account.

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