Climate Smart Agriculture for Food Security

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ABSTRACT

Today we find ourselves facing converging food and climate challenges of an unprecedented scale. While on the one hand we live in a world in which nearly 805 million people are suffering from chronic hunger, this situation is set to be exacerbated by climate change, which poses a major threat to food security.The Intergovernmental Panel on Climate Change (IPCC) predicts that food insecurity could increase by between 15- 40 per cent by the year 2050. Climate-smart agriculture (CSA) is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. Climate change disrupts food markets, posing population-wide risks to food supply. Climate change poses a threat to food access for both rural and urban populations by reducing agricultural production and incomes, increasing risks and disrupting markets. Threats can be reduced by increasing the adaptive capacity of farmers as well as increasing resilience and resource use efficiency in agricultural production systems.Agriculture and the food system have a unique and complex role to play within this context. Poor producers, the landless and marginalized ethnic groups are particularly vulnerable. It is estimated to have already reduced global yields of maize and wheat by 3.8% and 5.5% respectively. In this context, it is crucial that small-scale food producers are enabled to build farming practices that make them more resilient to such changes. CSA emphasizes agricultural systems that utilize ecosystem services to support productivity, adaptation and mitigation. Those includes integrated farming system, use of diversedrought, submergence, salinity varieties and breeds, crop rotation, short duration varieties, Improved nutrient management,Direct seeding, Dry direct seeding (DDS),Alternate wetting and drying (AWD) and aerobic rice, natural resource management etc.CSA can be achieved by coordinated actions of farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways through four main action areas like building evidence, increasing local institutional effectiveness, fostering coherence between climate and agricultural policies and linking climate and agricultural financing.

INTRODUCTION

Today we find ourselves facing converging food and climate challenges of an unprecedented scale. While on the one hand we live in a world in which nearly 805 million people are suffering from chronic hunger, this situation is set to be exacerbated by climate change, which poses a major threat to food security.

The Intergovernmental Panel on Climate Change (IPCC) predicts that food insecurity could increase by between 15- 40 per cent by the year 2050. Agriculture and the food system have a unique and complex role to play within this context. Firstly, as a source of food and nutrition security, they serve as a lifeline to millions, yet despite decades of increased production, millions of people remain without access to adequate food. Secondly, they are also major contributors to the causes of climate change, and therefore an integral part of the problem driving food insecurity. Thirdly, agriculture is a sector that is immensely vulnerable to the impacts of climate change, and in this context, it is crucial that small-scale food producers are enabled to build farming practices that make them more resilient to such changes.

To achieve food security for everybody it is therefore imperative that global agriculture and the food system are reformed in such a way that they: Are more resilient to the impacts of climate change (known as 'adaptation') and other shocks and crises (such as food price volatility, the ongoing economic crisis, and depletion of natural resources);

} Contribute less to global climate change (known as 'mitigation');

} Ensure the right to food of people through appropriate levels of production as well as through distribution and equitable access.

This unique role of agriculture presents a whole host of challenges which are technical, environmental, social, and economic in nature, and all relevant stakeholders – policy makers, academics, civil society, and scientists among them – grapple with ensuring food security in a climate-constrained world. Extensive research and debate have been increasingly emerging around this theme of late, and within this context, the concept of 'climate smart agriculture' (CSA) – a term first coined in 2009 and subsequently developed in 2010 by the Food and Agriculture Organization (FAO) of the United Nations (UN) – has surfaced as a "new conceptual framework that aims to simultaneously address" these interlinked challenges of food security and climate change.

As defined by the FAO, 'climate smart agriculture' "sustainably increases productivity, resilience (adaptation), reduces/ removes greenhouse gases (mitigation) while enhancing the achievement of national food security and development goals." However, CIDSE perceives some significant weaknesses in terms of content, particularly regarding:

Understanding the Challenges of climate change and food security

Business-as-usual scenarios of population growth and food consumption patterns indicate that agricultural production will need to increase by 70 percent by 2050 to meet global demand for food. The impacts of climate change will reduce productivity and lead to greater instability in production in the agricultural sector (crop and livestock production, fisheries and forestry) in communities that already have high levels of food insecurity and environmental degradation and limited options for coping with adverse weather conditions.

The agriculture sector is not only among the most vulnerable sectors to the impacts of climate change; it is also directly responsible for 14 percent of global greenhouse gas emissions.

In addition, the sector is a key driver of deforestation and land degradation, which account for an additional 17 percent of emissions. The agricultural sector can be an important part of the solution to climate change by capturing synergies that exist among activities to develop more productive food systems and improve natural resource management.

Sustainable utilization of natural resources will require management and governance practices based on ecosystem approaches that involve multi-stakeholder and multi-sectoralcoordination and cooperation. This is a crucial element for the transformation to climate-smart agriculture. Climate-smart agriculture is rooted in sustainable agriculture and rural development objectives which, if reached, would contribute to achieving the Millennium Development Goals (MDGs) of reducing hunger and improved environmental management. More productive and resilient agriculture is built on the sound management of natural resources, including land, water, soil and biodiversity. Conservation agriculture, agroforestry, improved livestock and water management, integrated pest management and ecosystem approaches to fisheries and aqua culture can all make important contributions in this area.

By 2050, an additional 2.4 billion people are expected to be living in developing countries, concentrated in South Asia and sub-Saharan Africa. Agriculture is a key economic sector and major employment source in these regions, but currently more than 20% of the population is on average food-insecure. About 75% of the world's poor live in rural areas, and agriculture is their most important income source. Raising agricultural productivity and incomes in the smallholder production sector is crucial for reducing poverty and achieving food security, as a key element and driver of economic transformation and growth, and within the broader context of urbanization and development of the non-farm sector. Projections indicate that globally, agricultural production will need to expand by 60 percent by 2050 to meet increased demand, and most of this will need to come from increased productivity.

Climate change is already hampering agricultural growth. According to IPCC, climate change affects crop production in several regions of the world, with negative effects more common than positive, and developing countries highly vulnerable to further negative impacts. Increases in the frequency and intensity of extreme events such as drought, heavy rainfall, flooding and high maximum temperatures are already occurring and expected to accelerate in many regions. Average and seasonal maximum temperatures are projected to continue rising, with higher average rainfall overall. However, these effects will not be evenly distributed. Water scarcity and drought in already dry regions are also likely to increase by the end of the century.

Climate change is estimated to have already reduced global yields of maize and wheat by 3.8% and 5.5% respectively6, and several researchers warn of dramatic decreases in crop productivity when temperatures exceed critical physiological thresholds. Increased climate variability exacerbates production risks and challenges farmers' coping ability. Climate change poses a threat to food access for both rural and urban populations by reducing agricultural production and incomes, increasing risks and disrupting markets.

Poor producers, the landless and marginalized ethnic groups are particularly vulnerable. The impact of extreme climate events can be long-lasting, as risk exposure and increased uncertainty affect investment incentives and reduce the likelihood of effective farm innovations, while increasing that of low-risk, low return activities.

Agriculture is also a principal contributor to planetary warming. Total non-carbon dioxide (CO2) greenhouse gas (GHG) emissions from agriculture in 2010 are estimated at 5.2-5.8 Gt CO2eq/year, comprising about 10-12% of global anthropogenic emissions. The highest-emitting agricultural categories are enteric fermentation, manure deposited on pasture, synthetic fertilizer, paddy rice cultivation, and biomass burning. The growth of emissions from land-use change is declining, although these still comprise about 12% of the total. Given the need for agricultural growth for food security, agricultural emissions are projected to increase. The main sources of projected emission growth, based on assumptions of conventional agricultural growth paths, can also have severe consequences for biodiversity and ecosystem services such as water quality and soil protection.

Essential elements of the CSA approach

Climate-Smart Agriculture (CSA) is an approach to help the people who manage agricultural systems respond effectively to climate change. The CSA approach pursues the triple objectives of sustainably increasing productivity and incomes, adapting to climate change and reducing greenhouse gas emissions where possible. This does not imply that every practice applied in every location should produce "triple wins". Rather the CSA approach seeks to reduce trade-offs and promote synergies by taking these objectives into consideration to inform decisions from the local to the global scales and over short and long time horizons, to derive locally-acceptable solutions.

The majority of the world's poor live in rural areas and agriculture is their most important income source. Developing the potential to increase the productivity and incomes from smallholder crop, livestock, fish and forest production systems will be the key to achieving global food security over the next twenty years. Climate change is expected to hit developing countries the hardest. Its effects include higher temperatures, changes in precipitation patterns, rising sea levels and more frequent extreme weather events. All of these pose risks for agriculture, food and water supplies. Resilience is therefore a predominant concern. Agriculture is a major source of greenhouse gas emissions. Mitigation can often be a significant co-benefit of actions to strengthen adaptation and enhance food security, and thus mitigation action compatible with national development priorities for agriculture is an important aspect of CSA.

The CSA Approach

CSA is not a set of practices that can be universally applied, but rather an approach that involves different elements embedded in local contexts. CSA relates to actions both on-farm and beyond the farm, and incorporates technologies, policies, institutions and investment.

Different elements of climate-smart agricultural systems include:

- Management of farms, crops, livestock, aquaculture and capture fisheries to balance near-term food security and livelihoods needs with priorities for adaptation and mitigation.
- Ecosystem and landscape management to conserve ecosystem services that are important for food security, agricultural development, adaptation and mitigation.
- Services for farmers and land managers to enable better management of climate risks/impacts and mitigation actions.
- Changes in the wider food system including demand-side measures and value chain interventions that enhance the benefits of CSA.

Unless we change our approach to planning and investment for agricultural growth and development, we risk misallocating human and financial resources, generating agricultural systems incapable of supporting food security and contributing to increasing climate change. Climate-smart agriculture (CSA) can avoid this "lose–lose" outcome by integrating climate change into the planning and implementation of sustainable agricultural strategies. CSA identifies synergies and trade-offs among food security, adaptation and mitigation as a basis for informing and reorienting policy in response to climate change.

In the absence of such efforts, IPCC projections indicate that agriculture and food systems will be less resilient and food security at higher risk. CSA calls for a set of actions by decision-makers from farm to global level, to enhance the resilience of agricultural systems and livelihoods and reduce the risk of food insecurity in the present as well as future.

The concept can be illustrated using an IPCC diagram of climate resilient transformation pathways, adapted to the specific case of agriculture**(Figure 1).** Agriculture faces a set of biophysical and socioeconomic stressors, including climate change. Actions taken at various decision points in the opportunity space determine which pathway is followed: CSA pathways result in higher resilience and lower risks to food security, whereas business as usual leads to higher risks of food security and lower resilience of food and agricultural systems.

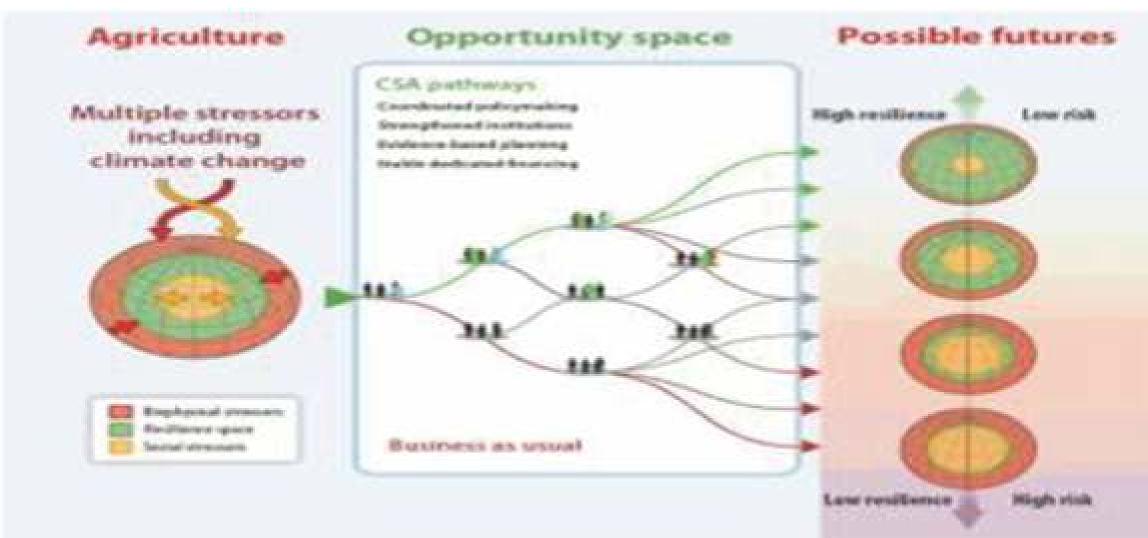

Figure 1 Climate-resilient transformation pathways for agriculture. Adapted from ref. 4, © IPCC.

The overall aim of CSA is to support efforts from the local to global levels for sustainably using agricultural systems to achieve food and nutrition security for all people at all times, integrating necessary adaptation and capturing potential mitigation. Three objectives are defined for achieving this aim: 1) sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development; 2) adapting and building resilience to climate change from the farm to national levels; and 3) developing opportunities to reduce GHG emissions from agriculture compared with past trends. Although CSA aims to attain all three objectives, it does not imply that every practice applied in every location should generate "triple wins". CSA requires consideration of all three objectives, from the local to the global scales and over short and long time horizons, to derive locally-acceptable solutions. The relative importance of each objective varies across locations and situations, as do potential synergies and trade-offs between objectives. Recognition of trade-offs is particularly important in developing countries, where agricultural growth and adaptation for food security and economic growth are a priority, and where poor farmers are the most affected by – but have contributed least to – climate change. Mitigation can often be a significant co-benefit of actions to improve food security and adaptation, but realizing this benefit may involve additional costs. Identification of the costs of low-emission growth strategies compared with conventional high-emission growth paths can help to link agricultural development efforts that generate mitigation co-benefits to sources of climate finance.

CSA stresses the importance of building evidence to identify viable options and necessary enabling activities. CSA provides tools for assessing different technologies and practices in relation to their effects on national development and food security objectives under the site-specific effects of climate change.

CSA emphasizes agricultural systems that utilize ecosystem services to support productivity, adaptation and mitigation. Examples include integrated crop, livestock, aquaculture and agroforestry systems; improved pest, water and nutrient management; landscape approaches; improved grassland and forestry management; practices such as reduced tillage and use of diverse varieties and breeds; integrating trees into agricultural systems; restoring degraded lands; improving the efficiency of water and nitrogen fertilizer use; and manure management, including the use of anaerobic bio-digesters. Enhancing soil quality can generate production, adaptation and mitigation benefits by regulating carbon, oxygen and plant nutrient cycles, leading to enhanced resilience to drought and flooding, and to carbon sequestration. These supply-side changes need to be complemented by efforts to change consumption patterns, reduce waste, and create positive incentives along the production chain.

What is needed for effective implementation of CSA?

Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.

CSA is an approach for developing agricultural strategies to secure sustainable food security under climate change. CSA provides the means to help stakeholders from local to national and international levels identify agricultural strategies suitable to their local conditions. CSA is one of the 11 Corporate Areas for Resource Mobilization under the FAO's Strategic Objectives. It is in line with FAO's vision for Sustainable Food and Agriculture and supports FAO's goal to make agriculture, forestry and fisheries more productive and more sustainable".

Urgent action from public, private and civil society stakeholders at the international to local levels is required in four areas: 1) building evidence and assessment tools; 2) strengthening national and local institutions; 3) developing coordinated and evidence-based policies; and 4) increasing financing and its effectiveness.

The current evidence base is inadequate to support effective decision-making, and largely inaccessible to decision-makers at the national and local levels. The spatial and temporal scales of much work addressing climate change impacts on agriculture are not appropriate for national and local-level planning. This is because of uncertainties associated with the outputs of climate models; technical issues associated with the downscaling of models to scales that are more appropriate for decision support; and the limited information on future changes in climate variability at such scales and their impacts on agriculture, which may be much more important for local communities than long-term trends in climate variables. The development and application of problem-oriented approaches to adaptation planning have considerable potential in identifying robust actions in the face of uncertainty.

Synergies among global, regional and local studies can also be exploited. Tools are needed for evaluating the adaptation and mitigation potential of different policies and technologies from local to global scales, covering the impacts of both extreme events and slow-onset changes on agriculture and food security, assessing means of increasing resilience in agriculture and food systems, and identifying options for, and costs of reducing emission growth. Landscape approaches and analysis of the options in existing foresight and scenario initiatives can greatly increase the effectiveness of research efforts at the local and international levels.

Another major gap in the evidence base is identifying barriers to the adoption of agricultural practices that respond to climate change, and means of overcoming these barriers, focusing on the most vulnerable, including smallholder producers, women, the poor and marginalized groups. Although farmers are adapting to changing climate conditions, the adoption of potentially beneficial practices is often low. There is particular need for robust studies that improve understanding of what works where and why in different agro-ecologies and farming systems, facilitating identification of what constitutes "climate smartness" in different biophysical and socio-economic contexts.

CSA's second priority action area is strengthening national and local institutions to support adaptive capacity through enhancing people's access to assets, including information. Institutional development has long been a major thrust of agricultural development strategies, although inadequate design or financing has resulted in mixed success30. Empirical evidence suggests that four main areas need public support to complement private efforts: 1) extension and information dissemination, particularly on using evidence to adapt practices to local conditions; 2) coordinated efforts where practices generate positive spillover benefits, for instance by reducing flood risks or pest outbreaks, or preserving biodiversity; 3) comprehensive risk management strategies for managing extreme weather events that affect many farmers simultaneously; and 4) reliable, timely and equitable access to inputs to support resource-use efficiency.

National public, private and civil society stakeholders have key roles in reducing information costs and barriers. In addition to strengthening the capacities of extension systems to disseminate site-specific information, tools such as radio programs and information and communications technologies (ICTs) can be used. Real-time weather information via ICTs is already being deployed by public and private sector actors in agricultural value chains in many countries, and could be greatly extended to include information relevant to CSA practices.

Climate change gives rise to new and increased demands for collective action. Often, to achieve the scale necessary to significantly reduce risks associated with extreme weather events, coordinated efforts are required by many farmers, those involved in managing communal resources and those managing public lands. Multi-stakeholder dialogues to support improved governance of tenure systems for land and water that take into account the interests of women, poor and marginalized groups are a promising direction, in addition to more traditional efforts to increase tenure security over privately held and managed land.

Comprehensive risk management strategies require a better understanding of the robustness of different risk management instruments under climate uncertainty, and coordination of actions by public, private and civil society actors from the international to local levels. National governments could provide mechanisms for proactive and integrated risk management, such as a national board that coordinates risk management strategies and institutions for risk monitoring, prevention, and response. The private sector can play a key role in risk management, but effective engagement must be enabled by transparent, efficient and enforceable regulations and innovative public-private partnerships. Social protection programs that guarantee minimum incomes or food access also affect risk exposure, with potential impacts on production choices, and there has been considerable expansion globally of such programs in recent years. CSA practices may require that farmers have access to specific inputs, such as tree seedlings, seeds or fertilizers. Lack of such inputs constrains widespread adoption. Timely access to fertilizer is a key determinant of productivity and efficient resource use, but is often lacking. Innovative means of input delivery, including those that rely on ICTs, can address these issues.

The third priority action area for CSA is building enabling policy and regulatory frameworks through increased coordination of agricultural, climate change/environmental and food system policies. An enabling policy environment requires alignment across policy domains, facilitated by dialogue across relevant ministries to address trade-offs, gaps and overlaps. Coordination is particularly important among national agricultural policies, strategies and investment plans and climate change instruments, including national adaptation programmes (NAPs), nationally appropriate mitigation actions (NAMAs) and climate change investment plans. Of the 44 countries planning NAMAs, 18 have identified agricultural activities as a priority(http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php). Participatory scenario development involving structured dialogue between agriculture, food security and climate change stakeholders can guide strategic thinking where complexity, multiple players and future uncertainty are involved.

International support for national efforts must be built on coordinated approaches to climate change, agricultural and food security policy areas, to ensure that capacity strengthening, technology development/transfer and financing enable national CSA actions. This requires greater coherence across multilateral policy processes, including those of the United Nations Framework Convention on Climate.

Change (UNFCCC), development of the post-2015 Sustainable Development Goals, and work on agricultural and food security policy by the Committee on World Food Security and Nutrition (CFS). The conclusions recently agreed by the Subsidiary Body for Scientific and Technological Advice (SBSTA) at the UNFCCC

Climate Talks (Bonn, June 2014), earlier discussion of food security and climate change at the CFS, and discussion in the UNFCCC on integrated approaches to land, may all help to align global policy.

The fourth priority action area is increasing and improving the targeting of financing to support the transition to CSA. Linking climate finance to traditional sources of agricultural finance is an important part of these efforts. Adapting agricultural systems will require increased upfront investment, and identifying and crediting mitigation co-benefits generated through the adaptation process is an important means of augmenting financial resources (see Box 1).

Investment finance for agriculture is insufficient to meet demand, and is often poorly targeted. Although climate finance may increase significantly in future years, it is still likely to meet only a relatively small share of total agricultural investment needs, which are estimated at US$209 billion per year by 2050 to increase production just to meet increased demand. The most promising climate financing sources for CSA include: 1) the Adaptation Fund, an innovative financing mechanism that focuses on the needs of the most vulnerable communities and the possibility of direct access; 2) the Global Environment Fund (GEF); and 3) the Green Climate Fund (GCF). For its sixth programming period from 2014 to 2018, the GEF replenishment amounts to US$4.43 billion, with US$1.26 billion for the climate change program area and US$431 million for the land degradation focal area. The GCF is expected to disburse US$100 billion annually by 2020 to cover adaptation and mitigation in all sectors, using both public and private resources.

Box 1: Mitigation and food security

Food security and climate change can be addressed together by transforming agriculture and adopting practices that are "climate-smart". Farmers are under the greatest threat from climate change, but they also play a major role in addressing it. Climate-smart farming techniques can increase agricultural productivity and incomes, make rural communities more resilient to climate change and where possible, mitigate climate change.

FAO and its partners are aware that achieving the transformations required for CSA and meeting these multiple objectives requires an integrated approach that is responsive to specific local conditions, diversifies food sources and strengthens the resilience of farmers' livelihoods.

Given the site-specific effects of climate change, together with the wide variation in agro ecological zones and farming, livestock and fishery systems, the most effective climate-smart strategies will vary within countries.

Sharing practices and technologies can be done through increased cooperation, and information sharing among stakeholders; and the development of outreach, extension and technical assistance.

Local knowledge, as well as the capacity to link research and local activities, plays a key role in scaling up the CSA approach to reinforce the resilience of farmers' livelihoods.

The idea that agriculture should mitigate climate change is controversial because of the sector's importance for food security. However, agriculture is projected to be a major source of emissions growth, which threatens future food security. CSA therefore prioritizes food security but also considers the potential and costs of capturing mitigation benefits. Mitigation is leveraged to support food security and adaptation, rather than hampering or harnessing them.

For example, more efficient resource use in agricultural production systems offers considerable potential for increasing agricultural incomes and the resilience of rural livelihoods while reducing the intensity of agricultural emissions. Increasing resource-use efficiency requires evidence on which practices contribute most to efficiency across heterogeneous agro-ecologies and production systems, and the barriers to their adoption.

Improved livestock feeding practices illustrate these issues. Options for improved feeding can be identified in different production systems, with potential to increase returns and the resilience of producers. However, adoption rates of improved livestock feeding practices have rarely exceeded 1% per year. Accelerated adoption could generate significant growth in livestock productivity and incomes and approximately 7% of global agricultural mitigation potential to 2030. Barriers vary by system and location, but generally involve institutional gaps and weaknesses; missing and weak institutions also constitute a significant barrier to adoption of sustainable land management practices that enhance resilience.

Directing climate finance to support institutional investments that can accelerate adoption of practices for increasing resource-use efficiency represents an important step towards climate-resilient development in agriculture. Public sector finance for adaptation and mitigation is likely to be the most important source of climate finance for CSA in developing countries, including bilateral donors, multilateral financial institutions, the GEF, and the emerging GCF, which can channel funds through national policy instruments such as NAPS and NAMAs.

CONCLUSION

Climate change alters agricultural production and food systems, and thus the approach to transforming agricultural systems to support global food security and poverty reduction. Climate change introduces greater uncertainty and risk among farmers and policy-makers, but need not lead to analysis paralysis.

An integrated, evidence-based and transformative approach to addressing food and climate security at all levels requires coordinated actions from the global to local levels, from research to policies and investments, and across private, public and civil society sectors to achieve the scale and rate of change required. With the right practices, policies and investments, the agriculture sector can move onto CSA pathways, resulting in decreased food insecurity and poverty in the short term while contributing to reducing climate change as a threat to food security over the longer term.

Received *: August 01, 2018*
Accepted *: August 17, 2018*

REFERENCES

1. Food and agriculture organization of the United Nations http://www.fao.org/climate-smart-agriculture/overview/en/
2. *Rural Poverty Report 2011* (International Fund for Agricultural Development, 2011).
3. Alexandratos, N. &Bruinsma, J. *World Agriculture Towards 2030/2050: The 2012 Revision* ESA Working paper No. 12–03 (FAO, 2012).
4. Olsson, L. *et al.* in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (eds Field, C. B. *et al.*) 793–832 (IPCC, Cambridge Univ. Press, 2014).
5. Smith, P. *et al. in Climate Change 2014: Mitigation of Climate Change* Ch. 11 (IPCC, Cambridge Univ. Press, 2014).
6. IPCC *Climate Change 2014: Mitigation of Climate Change* (edsEdenhofer, O. *et al.*) 29, note 4 (Cambridge Univ. Press, 2014).
7. *Climate-Smart Agriculture Sourcebook* Executive Summary (Food and Agriculture Organization of the United Nations, 2013).
8. Vermeulen, S. J., Campbell, B. M. & Ingram, J. S. I. (2012). Climate change and food systems. Annu. Rev. Env. Resour. 37, 195–222.
9. Vervoort, J. M. *et al.* Challenges to scenario-guided adaptive action on food security under climate change. *Global Environ. Change* http://dx.doi.org/10.1016/j.gloenvcha2014.03.001 (2014).
10. *Financing Climate-smart Agriculture* 375–406 (Climate-Smart Agriculture Sourcebook Module **14**, FAO, 2013).
11. Vermeulen, S. J. *et al.* Addressing uncertainty in adaptation planning for agriculture. *Proc. Natl Acad. Sci. USA* **110,** 8357–8362 (2013).
12. Chibonga, D. (2016). Climate Smart Agriculture to Foster Food Production. www.nasfam.org Prepared for WFO Annual General Assembly in Livingstone, Zambia - May 4-6, 2016
13. Walthall, C and Hatfield, J. Report on Climate Change and Agriculture: Effects & Adaptation http://www.usda.gov/oce/climate_change/effects.htm
14. FAO, Climate-Smart Agriculture.
15. Neufeldt et al., Beyond climate-smart agriculture: toward safe operating spaces for global food systems, Agriculture & Food Security, 2013.

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