PERSPECTIVE
PUBLISHED ONLINE: 26 NOVEMBER 2014 | DOI: 10.1038/NCLIMATE2437

nature climate change

Climate-smart agriculture for food security

Leslie Lipper *et al.**

Climate-smart agriculture (CSA) is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. Widespread changes in rainfall and temperature patterns threaten agricultural production and increase the vulnerability of people dependent on agriculture for their livelihoods, which includes most of the world's poor. Climate change disrupts food markets, posing population-wide risks to food supply. Threats can be reduced by increasing the adaptive capacity of farmers as well as increasing resilience and resource use efficiency in agricultural production systems. CSA promotes coordinated actions by farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways through four main action areas: (1) building evidence; (2) increasing local institutional effectiveness; (3) fostering coherence between climate and agricultural policies; and (4) linking climate and agricultural financing. CSA differs from 'business-as-usual' approaches by emphasizing the capacity to implement flexible, context-specific solutions, supported by innovative policy and financing actions.

By 2050, an additional 2.4 billion people are expected to be living in developing countries, concentrated in South Asia and sub-Saharan Africa. In these regions, agriculture is a key economic sector and major employment source, but currently more than 20% of the population is on average food-insecure[1]. About 75% of the world's poor live in rural areas, and agriculture is their most important income source[2]. 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% by 2050 to meet increased demand, and most of this will need to come from increased productivity[3].

Climate change is already hampering agricultural growth. According to the Intergovernmental Panel on Climate Change (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[4]. 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[5]. Average and seasonal maximum temperatures are projected to continue rising, with higher average rainfall overall. These effects will not, however, be evenly distributed. Water scarcity and drought in already dry regions are also likely to increase by the end of the century[5].

Climate change is estimated to have already reduced global yields of maize and wheat by 3.8% and 5.5% respectively[6], and several researchers warn of steep decreases in crop productivity when temperatures exceed critical physiological thresholds[7,8]. Increased climate variability exacerbates production risks and challenges farmers' coping ability[9]. 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[10]. 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[11,12].

Agriculture is also a principal contributor to planetary warming. Total non-carbon-dioxide (CO_2) greenhouse gas (GHG) emissions from agriculture in 2010 are estimated at 5.2–5.8 gigatonnes of CO_2 equivalent per year (ref. 13), making up about 10–12% of global anthropogenic emissions[14]. 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 make up 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

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 will be 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 the future. The concept can be illustrated using an IPCC diagram of climate-resilient transformation pathways, adapted to the specific case of agriculture[15] (Fig. 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.

* A full list of authors and their affiliations appears at the end of the paper.

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[16]. 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. It 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 builds on existing experience and knowledge of sustainable agricultural development. Sustainable intensification[17] is a cornerstone, as more efficient resource use contributes to adaptation and mitigation via effects on farm productivity and incomes as well as reduced emissions per unit of product. Sustainable intensification on existing agricultural land has considerable mitigation potential by reducing the conversion of forest and wetlands, although additional protection measures may be required.

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[18]. 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[19].

Although farmers have always dealt with variability and uncertainty in weather patterns, the increased uncertainty that climate change imposes calls for more flexible and rapid response capacity. Building resilience means reducing the risk of becoming food-insecure and increasing the adaptive capacity to cope with risks and respond to change[20]. This may involve incremental or transformative actions. Incremental changes include better information provision; timely access to production inputs; shifts in production techniques to enhance ecosystem services and maintain productivity under climate shocks; improved market governance to reduce price volatility, and expanded insurance and safety net programmes. Transformative

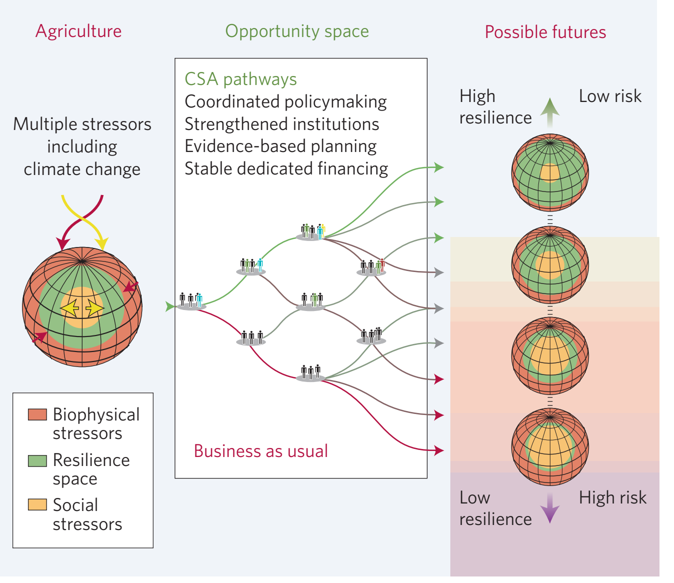

Figure 1 | Climate-resilient transformation pathways for agriculture. Adapted from ref. 4, © IPCC.

changes can involve major shifts in agricultural production (for example from crops to livestock, among crops, and from lower to higher elevations) or sources of livelihoods (for example increased reliance on non-farm income).

What is needed for effective implementation of CSA?

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[21], which may be much more important for local communities than long-term trends in climate variables[22]. The development and application of problem-oriented approaches to adaptation planning have considerable potential in identifying robust actions in the face of uncertainty[23]. Synergies among global, regional and local studies can also be exploited[24]. 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[25] and analysis of the options in existing foresight and scenario initiatives[26,27] 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[28,29]. 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 success[30]. 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[28].

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 programmes 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[31], and coordination of actions by public, private and civil society actors from the international to local levels[32]. 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 programmes 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 programmes 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[33]. 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

Box 1 | Mitigation and food security.

The idea that agriculture should mitigate climate change is controversial because of the sector's importance for food security. But agriculture is projected to be a major source of emissions growth, which threatens future food security[12]. 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[12]. 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. But 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 offers 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[27].

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[35].

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[34].

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[35]. 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[34].

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)[36]. 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 programme area and US$431 million for the land degradation focal area[37]. 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[35].

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 policymakers, but need not lead to analysis paralysis[38]. 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 24 March 2014; accepted 29 September 2014; published online 26 November 2014

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Acknowledgements
The views expressed in this article are those of the authors and do not necessarily reflect the views or policies of FAO.

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Competing financial interests
The authors declare no competing financial interests.

Leslie Lipper[1]*, Philip Thornton[2,3], Bruce M. Campbell[3,4], Tobias Baedeker[5], Ademola Braimoh[5], Martin Bwalya[6], Patrick Caron[7], Andrea Cattaneo[1], Dennis Garrity[8], Kevin Henry[9], Ryan Hottle[4,5,10], Louise Jackson[11], Andrew Jarvis[3,4], Fred Kossam[12], Wendy Mann[1], Nancy McCarthy[13], Alexandre Meybeck[1], Henry Neufeldt[9], Tom Remington[14], Pham Thi Sen[15], Reuben Sessa[1], Reynolds Shula[16], Austin Tibu[17] and Emmanuel F. Torquebiau[8]

[1]Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy. [2]International Livestock Research Institute (ILRI), PO Box 30709, Nairobi 00100, Kenya. [3]Consultative Group on International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture, and Food Security (CCAFS), University of Copenhagen, Faculty of Science, Department of Plant and Environmental Sciences, Rolighedsvej 21, DK-1958, Frederiksberg C, Copenhagen, Denmark. [4]International Center for Tropical Agriculture (CIAT), Km 17, Recta Cali-Palmira, Apartado Aéreo 6713, Cali, Colombia. [5]World Bank, Agriculture Global Practice, 1818 H Street NW, Washington DC 20433, USA. [6]Ohio State University (OSU) International Programs in Agriculture and School of Environment and Natural Resources Office of International Programs in Agriculture, 113 Agricultural Administration Building, The Ohio State University, 2120 Fyffe Road, Columbus, Ohio 43210, USA. [7]New Partnership for Africa's Development (NEPAD), International Business Gateway New Road and 6th Road, Midridge Office Park c/o Challenger and Columbia Avenue, Block B Midrand Johannesburg 1685, South Africa. [8]French Agricultural Research Centre for International Development (CIRAD), TA 179/04, Avenue Agropolis, 34398 Montpellier Cedex 5, France. [9]World Agroforestry Centre (ICRAF), United Nations Avenue, Gigiri, PO Box 30677-00100 Nairobi, Kenya. [10]Colorado State University, School of Global Environmental Sustainability, 108 Johnson Hall, Fort Collins, Colorado 80523, USA. [11]University of California, Davis, Department of Land, Air and Water Resources, 3144 PES Building, University of California, One Shields Avenue, Davis, California 95616, USA. [12]Ministry of Environment and Climate Change Management, Malawi, Department of Climate Change and Met Services, PO Box 1808 Blantyre, Malawi. [13]Law, Economics and Agriculture for Development (LEAD) Analytics, 5136 Nebraska Avenue NW, Washington DC, USA. [14]International Potato Center (CIP), PO Box 31600, Lilongwe 3, Malawi. [15]Northern Mountainous Agriculture and Forestry Science Institute, Viet Nam (NOMAFSI), Phu Ho Commun, Phu Tho District, Phu Tho Province, Viet Nam. [16]Ministry of Agriculture and Livestock, Zambia, Department of Agriculture, Mulungushi House, PO Box 50291, Lusaka, Zambia. [17]Ministry of Agriculture and Food Security, Malawi, Land Resources Conservation Department, PO Box 30291, Lilongwe, Malawi. *e-mail: leslie.lipper@fao.org