FUTURE of FOOD

Shaping a Climate-Smart Global Food System

Foreword by Dr. Jim Yong Kim

WORLD BANK GROUP

1818 H Street NW
Washington, DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org
www.worldbank.org/foodsecurity
Twitter: @WBG_Agriculture
Email: feedback@worldbank.org

The report was prepared by a core team consisting of Irina Klytchnikova, Marc Sadler, Robert Townsend, Svetlana Edmeades, Vikas Choudhary, Sarwat Hussain, Holger Kray, Erick Fernandes, Gene Moses, James Cantrell, Xenia Zia Morales, and Michele Pietrowski. The report was completed with overall guidance by Juergen Voegele, Ethel Sennhauser, and Marianne Fay; benefited from peer review by Dina Umali-Deininger, Carter Brandon, Richard Damania, Ulf Narloch, John Nash, Luc Christiaensen, and Michael Morris; with helpful suggestions and contributions from Punam Chuhan-Pole, Ana Luna, Priti Kumar, and Kathryn Hollifield; and editing by Jane Sunderland. Special gratitude to the CIAT team for providing the info-graphic, "Climate-Smart Agriculture for Policy Makers."

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FOREWORD

The agriculture sector is a mainstay of national economies across the developing world. Agriculture is a major provider of food, nutrition, jobs, and export earnings, and the sector is key to improving stewardship of the environment.

Farming affects every member of the human family, and is the basis of food security at national, regional, and global levels. A well-performing agriculture sector is vital for achieving the World Bank Group's vision of a sustainable global food system that can feed every person, every day, everywhere with a nutritious and affordable diet.

Climate change and agriculture are inextricably linked. Droughts, floods, and rising temperatures are cutting crop yields, threatening food, fish and meat supply, and pushing poor people deeper into poverty.

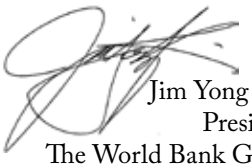
Agriculture and land-use changes contribute 25 percent of heat-trapping greenhouse gas emissions. Without collective action, this number will likely rise. Food demand is projected to increase by at least 20 percent globally over the next 15 years—with the largest increases expected in sub-Saharan Africa, South Asia, and East Asia—and a climate-smart food system is urgently needed.

We must have a greater push to support widespread adoption of climate-smart agriculture in efforts to secure the triple win of higher agricultural productivity, increased resilience to climate change, and lower greenhouse gas emissions.

The World Bank Group is pleased to present "Future of Food: Shaping a Climate-Smart Global Food System," at the 2015 Annual Meetings being held in Lima, Peru. The report aims to help improve the productivity and resilience of the current food system, and to make agriculture part of the solution to climate change.

It presents compelling evidence and new tools for policymakers, serving as a guide to better address the impacts of a warming climate on agriculture and food production. As the international community works toward the new Sustainable Development Goals, the nexus of food security, productivity, and climate change must come into sharper focus. This report argues that climate-smart agriculture is central to efforts to end extreme poverty by 2030 and boost shared prosperity.

We at the World Bank Group are committed to working with our partners to shape a global food system that feeds all and creates a healthier, more prosperous, and sustainable world.



Jim Yong Kim
President
The World Bank Group

SUMMARY AND KEY MESSAGES

Attaining a significant share of the new Sustainable Development Goals (SDGs) rests upon the ability to ensure the food system is productive, resilient, and contributes to tackling climate change. The growing body of operational experience implementing Climate-Smart Agriculture (CSA) points to a large spectrum of approaches that deliver productivity and resilience gains alongside lower emissions. This paper advocates for an increasing shift toward securing a triple win by implementing agriculture and food production practices that not only boost productivity but also enhance resilience and lower greenhouse gas emissions (GHG)—the three pillars that form the basis of CSA.

Key messages

- **Meeting the rising demand for food and ending hunger and food insecurity requires a climate-smart food system that improves agricultural productivity, has greater resilience to climate change and lowers greenhouse gas emissions.** Droughts, floods and rising temperatures are already cutting crop yields, threatening food, fish and meat supply and pushing people deeper into poverty. Climate change and the effects of climate shocks are dampening the prospects for future productivity growth. Agriculture and land use changes already contribute 25 percent of greenhouse gas emissions. A more climate-smart food system is urgently needed to address these challenges.
- **There is a growing spectrum of interventions—policies, practices and innovations—that must help secure the triple win of higher agricultural productivity, increased resilience to climate change and lower emissions.** But in a world of constrained resources, prioritization of investments in climate-smart agriculture (CSA) is crucial. New tools are available that can help policy makers and stakeholders assess opportunities, balance trade-offs and facilitate identification of entry points for smart, targeted interventions and more efficient investments.
- **The new Sustainable Development Goals to end global poverty and hunger by 2030 offer a major opportunity to place the need for a climate-smart food system at the front and center of the development agenda and debate.** This paper calls on the development community, scientists, investors, and civil society to rally behind governments and farmers to support integrated approaches and overcome barriers to adoption of CSA.

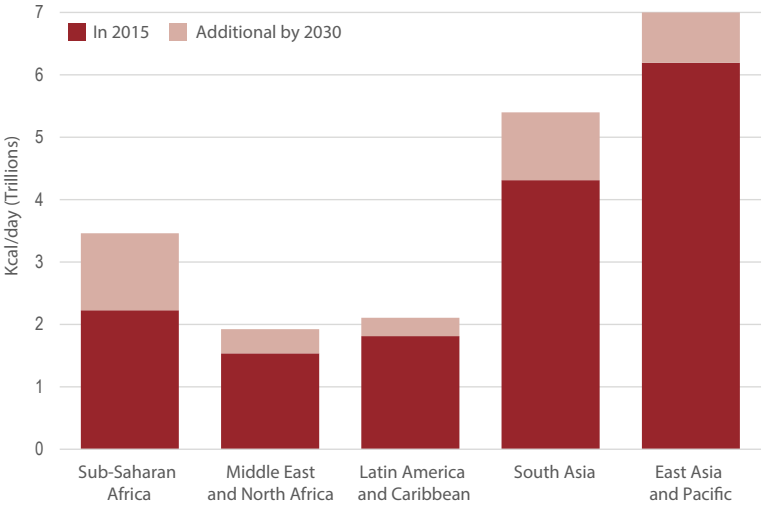
First, the paper highlights why ensuring a more climate-smart food system is needed; second, it identifies what practices and approaches can help accomplish this endeavor and offers a guide on how these can be better prioritized at the country level; and third, it focuses on how these improved practices and approaches can be more broadly developed and adopted through improved incentives, knowledge, science, and finance.

Why Is a More Climate-Smart Food System Needed?

The world has made impressive progress over the last 25 years in the continuing fight against poverty—but a further push is needed. Globally, the number of people living in extreme poverty fell from 1.9 billion in 1990 to an estimated 900 million today. Though the majority of the poor still reside in Sub-Saharan Africa and South Asia, the rate of poverty reduction has accelerated over the last decade. Nevertheless, 800 million people go to bed hungry every day, and one in every ten people in the world is undernourished. To end poverty by 2030, it is crucial not only to accelerate growth but to make it more broad-based, both within and among countries.[1] The recently agreed Sustainable Development Goals to end global poverty and hunger by 2030 will require faster progress, particularly in the poorest countries.

Improving agricultural performance will be central to addressing the poverty and food insecurity challenge, as three-quarters of poor people still live in rural areas, and nearly two-thirds of the world's poor people work in agriculture. Food demand is projected to rise by at least 20 percent globally over the next 15 years, with the largest increases projected in Sub-Saharan Africa, South Asia, and East Asia (Figure 1).[2] Food production in Sub-Saharan Africa will need to increase by about 60 percent over the next 15 years to meet the rising demand for food and to eliminate hunger.[3] If these food needs are to be met by productivity gains alone, cereal yields in Sub-Saharan Africa will need to increase at 3 percent per year, which is over 40 percent higher than the 2.1 percent gains achieved from 2000 to 2013. Higher cereal yields in Sub-Saharan Africa

Figure 1: Growth in Total Food Consumption by 2030, Relative to 2015



Source: World Bank staff estimates based on N. Alexandratos and J. Bruinsma 2012, "World Agriculture Towards 2030/2050: The 2012 Revision." ESA Working Paper 12-30 (Rome: FAO, 2012).

are closely correlated with a higher share of the population living above the poverty line.

Sustained agricultural productivity gains require greater resilience to climate shocks and climate change

Climate shocks already impose large economic costs when crop yields and livestock productivity suffer from droughts, floods, and heat waves. In 2009, almost 20 percent of maize production in Mexico was lost due to drought, and similar losses occurred again in 2011 as a result of the so-called White Corn Freeze. During the 2010 floods in Colombia, 380,000 hectares of crop lands and pastures were flooded, and 30,000 head of livestock died. Cyclones destroyed nearly one-third of Sri Lanka's rice crop and badly damaged most of Madagascar's rice-producing areas in 2011. When major global food producers are hit by extreme weather, depending on the magnitude of crop failure and policy response, the adverse consequences may ripple throughout the global food system, resulting in high economic losses, adding to volatility of food prices, and depressing incomes of farmers and consumers alike. For example, in Uganda growth in agricultural income has been the principal driver of poverty reduction in the last decade, and in turn drought has had a greater impact on agricultural growth and incomes of the bottom 40 percent than any other shock (for example, shocks from health, floods, and conflict). In Ethiopia—a country with historically high vulnerability to low and erratic rainfall—households that suffered famine in the 1980s were still experiencing low-income growth rates during the 1990s, and as recent evidence shows, drought is the dominant risk compared to price, health, and other shocks.

Climate change is projected to reduce agricultural yields and livestock productivity, worsening the effect of climate shocks on the food system. Estimates of crop yield and livestock losses vary greatly, but most global

climate models project severe and adverse consequences, especially for the world's most food-insecure regions. Without adaptation, Asia and Africa will suffer particularly severe yield declines by 2030 in important food growing areas—wheat in South Asia, rice in Southeast Asia, and maize in southern Africa.[4] Yield decreases of more than 7 percent are likely by 2030 in Africa's Sahelian region, and they could exceed 30 percent in some areas of the Arabian Peninsula, the Horn of Africa, and southern Africa by 2080.[5] Substantial increase in drought risk—a major driver of crop and livestock production shortfalls—is projected for large parts of the Middle East, North Africa, and South America. Depending on region and types of production systems, water scarcity will result in less productive pastures, lower dairy yields, and higher risk of the spread of diseases.[6] In Latin America and Southeast Asia, floods and droughts during El Niño/La Niña episodes, which already cause heavy losses in agriculture, are likely to double in frequency.[7]

Climate change will therefore hamper our ability to feed everyone and eradicate hunger. Achieving the needed food productivity and poverty reduction gains will be particularly difficult in food-insecure regions as the challenge is further magnified by the very high vulnerability of these locations to climate change.[8]

Agriculture needs to reduce its greenhouse gas emissions and become part of the solution to tackle climate change

Agriculture and land use change is a large contributor to global warming, accounting for a quarter of total greenhouse gas emissions. Projecting past trends, agriculture and other land use changes alone would comprise 70 percent of total allowable emissions across all sectors in 2050 needed to limit global temperature increases to 2°C.[9] More action is urgently needed to reduce emissions from agriculture, an imperative that can be met by including agriculture in current and future major intergovernmental climate change discussions. When considering emissions from the overall food system, including the emissions from energy and transport throughout the food production and consumption chain, the magnitude of the needed reductions is likely to be even greater. So agriculture needs to be part of the solution to the climate change problem.

Delinking the growth of food production from the growth of emissions is also needed. Even in the world's poor countries,

WHAT IF AGROFORESTRY SPREAD ACROSS AFRICA'S DRYLANDS?

In Niger's Maradi region, farmer-led adoption of agroforestry restored 5 million hectares of degraded land, improved soil fertility through the planting of around 200 million nitrogen-fixing trees that naturally reduce the need for fertilizer, resulted in the tripling of millet yields and stored an additional 2 tons per hectare of carbon in soils and plants. Spreading agroforestry across 300 million hectares of Africa's drylands outside the boundaries of protected areas and where it is technically feasible would raise food production by an estimated 88 million tons and store an equivalent of one-third of global direct emissions from agriculture.

Note: See Endnote 9.

which contribute a small share of global emissions, policy makers will need to increasingly focus on the agriculture sector to seize opportunities for synergies and avoid lock-ins to a higher emissions growth path; a focus on mitigation may be warranted in order to delink economic growth from the growth of emissions.

Agriculture also has the biophysical potential to offset and sequester about 20 percent of total annual emissions through improved soil management techniques.[10] Currently, the world's soils hold three times more carbon than the atmosphere. They have significant potential to absorb a larger amount of carbon from the atmosphere than they currently do.[11] Over the past century, unsustainable agriculture and other practices have degraded land, leading to the emission of billions of tons of carbon that was trapped in the soil. Restoring this carbon to the soil will not only sequester carbon from the atmosphere, but also boost food productivity, increase water retention (leading to greater resilience when droughts hit), bring land back into production (thereby reducing pressure on biodiversity and forests) and boost incomes benefiting the rural poor. In short, investing in carbon sequestration techniques in the agricultural sector can deliver food security and development outcomes while "buying time" for other major technology breakthroughs to deliver on the mitigation agenda. Policy makers and stakeholders will need to assess trade-offs carefully, and their task can be greatly assisted by more up-to-date climate information at the country and local levels.

What Type of Investments Will Ensure a More Climate-Smart Food System?

Globally, investments that better integrate the imperatives of the "triple win"—raising agricultural productivity, increasing adaptation and resilience to climate change, and reducing greenhouse gas emissions—are urgently needed. Past efforts have often focused on these aspects independently. We need increasingly to shift to addressing all three simultaneously—the "triple win."

A growing and diverse spectrum of practices show it is possible to simultaneously deliver higher agricultural productivity, greater climate resilience, and lower emissions. Important among these are silvopastoral livestock systems, agroforestry, intercropping, diversification of production systems toward less water- and emission-intensive crops, improved pasture management, better fertilizer use, minimum tillage, alternative wetting and drying of rice, biogas production from agricultural waste products/livestock manure, improved irrigation and drainage efficiency that includes lowering GHG emissions by reducing energy consumption of pumping stations, and reducing food loss and waste. Some of the recent stories highlighting success along the three pillars of CSA are shown in the snapshot "Examples of Diverse Approaches to Achieving Triple Wins of CSA." A focus on increasing synergies and multiple outcomes will not only help make progress toward global food security, but also enable agriculture to become part of the solution for tackling climate change. It is important to note that CSA is an approach that promotes a combination of investments, policies, and technology adoption that deliver multiple outcomes simultaneously within a practice, or across a landscape, production system, or supply chain.

SYNERGIES BETWEEN GREATER EFFICIENCY AND SUSTAINABLE USE OF LAND, WATER, AND INPUTS LEADING TO CSA

Farmers in China currently apply approximately 200 pounds of fertilizer per acre on average, whereas farmers in Africa apply less than 100 pounds on average. If application rates could be reduced in China and increased in Africa, the net impact could be an extra 175 million tons of food produced in Africa and a reduction of up to 360 million tons of carbon dioxide equivalent (CO_2-e) in China's emissions (and reduced farming costs).[i]

If alternative wetting and drying could be expanded to 100 percent of eligible areas globally, water consumption in agriculture could be cut by 30 percent, 200 million tons of CO_2-e emissions could be avoided, 65 million more tons of rice could be produced, and farmer incomes could be increased.[ii]

The FAO estimates that emissions from livestock can be reduced by between 18 and 30 percent concurrent with an increase in productivity if producers in given production systems and geographies adopt the practices currently used by the 10 percent of producers with the lowest emissions intensity.[iii]

Intensification needs to be complemented by policy planning, regulations, pricing, and financial incentive mechanisms to promote sustainable landscape and watershed management and reduce the added pressure from extensification that the gains in productivity may facilitate.

Note:
i. D. Charles, 2013. "Fertilized World." National Geographic. May.
ii. M. Richards and O. Sander 2014. "Alternate Wetting and Drying in Irrigated Rice." CGIAR Practice Brief. Washington, D.C.
iii. FAO Livestock: P.J. Gerber, H. Steinfeld, B. Henderson, A. Mottet, C. Opio, J. Dijkman, A. Falcucci, and G. Tempio 2013. "Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities." Food and Agriculture Organization of the United Nations (FAO). Rome.

Reducing food waste and food loss is key for boosting the CSA triple win by raising the overall food system productivity while delivering greater resilience and lower emissions by using less land, forests, and water resources. Food losses in industrialized countries are higher or comparable to those in developing countries, but in developing countries around 70 percent of the food losses occur before food reaches the final consumer, while in industrialized countries, around 70 percent of the food losses occur at retail and consumer levels. Food waste at consumer level in industrialized countries (estimated at 222 million tons) is almost as high as the total food production in sub-Saharan Africa (230 million tons).[12]

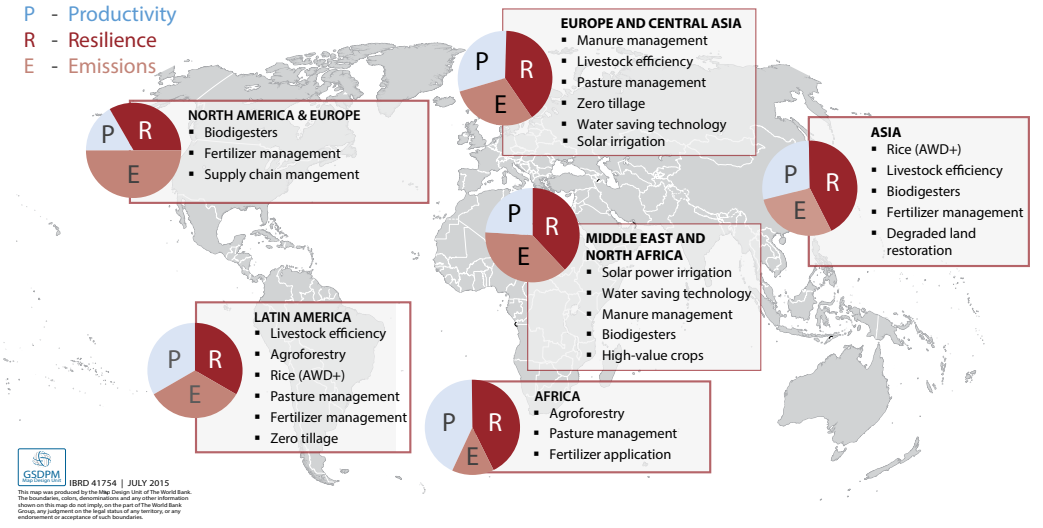
A growing menu of options are available that vary by region

Opportunities to achieve synergies between productivity and resilience, with the co-benefit of lower emissions, will vary by region. All countries need to contribute to lowering emissions through actions in all sectors, but richer countries are responsible for a far greater share of total emissions and need to make greater effort compared to poorer countries (Figure 2). More than 800 million people living in countries with per capita GDP below US$4,000 are responsible for only 1 percent of global CO_2 emissions. For them, investment in climate-smart agriculture should place a relatively higher weight on productivity growth and resilience

building.[13] However, even in those countries there are opportunities to ensure that this growth is attained through approaches that limit emissions and help sharply reduce the intensity of emissions for producing one kilogram of food. Nitrogen-fixing trees can help improve soil quality and raise farmer incomes in Africa's Sahel, and at the same time also deliver a mitigation co-benefit. There is a growing range of practices and landscape approaches that can deliver mitigation benefits at no additional cost. In other cases, mitigation options may incur a cost, but inaction today may have long-term or irreversible consequences such as deforestation, desertification, and severe soil degradation.[14] It is absolutely essential that support for agricultural research include a focus on mitigation. In particular, investment in agricultural research needs to increase dramatically to mobilize science for climate-smart agricultural practices benefiting smallholder farmers in that context.

Beyond individual practices, adopting integrated landscape or watershed approaches, supported by sound institutions and regulations can help deliver the "triple win." We cannot achieve food security without preserving the ecosystem services that forests provide. We cannot sustain forests without thinking how we will feed a growing population. And we cannot grow food without water. Gains in production efficiency and intensification of livestock and crop production systems deliver mitigation benefits if on balance water, forest and soil resources fall under less pressure from growing agricultural production.

Figure 2. Regional Variation of the Scope to Achieve CSA Triple Win



Source: World Bank staff estimates.

Note: This figure is for illustrative purposes only. The relative weight of the focus on productivity, resilience, and emissions is derived based on a qualitative assessment of the data on vulnerability hot spots of agricultural productivity in D. Wheeler 2011, Center for Global Development (accessed at: http://www.cgdev.org/page/mapping-impacts-climate-change) and the profile of emissions from agriculture by subsector derived from FAOSTAT data at regional level.

SNAPSHOT — EXAMPLES OF DIVERSE APPROACHES TO ACHIEVING TRIPLE WINS IN CSA

Climate-Smart Agriculture Keeps Rice Bowls Filled in Vietnam

In Vietnam, climate-smart approaches to rice cultivation have helped up to 33,000 farmers produce more rice while cutting costs and reducing methane emissions. Switching from flood irrigation to alternative wetting and drying of plots has reduced input costs by 20 percent, raised productivity by 5–10 percent, and significantly cut methane emissions and water use. Science, technology, outreach, training, and extension services for farmers and cooperatives through Farmer Field Schools; increased availability of certified seed; and better irrigation management techniques helped deliver the technology at large scale, and pave the way for expanding the project to all eight rice-growing provinces in the Mekong Delta.

Alternative wetting and drying techniques raised rice productivity by 5–10 percent, reduced water use, and cut methane emissions.

Climate-Smart Agriculture Delivering Results in India

Livestock: A government program to support the national dairy sector improving animal feed, nutrition and fodder development is under way in climatically vulnerable agro-ecological regions in 15 states. The program boosts cattle productivity by promoting breeds that are resilient and adapted to local conditions and promotes improved animal nutrition through the Ration Balancing Program. Feed costs and **methane emissions both fell by 12 percent**, a healthier and more productive pool of cattle is making the system more climate-resilient, and at least one-third of the beneficiary farmers are women.

Land and watershed management: In Himachal Pradesh state, improved management of the Mid-Himalayan watershed as part of a national watershed management program has given farmers US$8 million in carbon credits from the Prototype Carbon Fund. To date, up to 10,000 hectares of nonarable agricultural wastelands have been restored and degraded forests have been afforested. On arable lands, more than 10,000 water harvesting structures have been built, expanding irrigation potential by nearly 9,000 hectares benefiting some 54,000 rural households (24 percent of which are vulnerable households) increasing their resilience to drought. Karnataka and Bihar states are also implementing watershed management and climate resilience programs—focusing on raising productivity of farming systems while protecting soils and water—that at the same time deliver mitigation benefits. A national "climate knowledge base" helps regional watershed management projects attain triple-win outcomes, by enhancing the understanding of hydrology and trends in future water availability in relation to global warming, and facilitating land use planning through local, integrated water-soils-farming systems information.

New sorghum and millet varieties yield 1.5 to 2 tons per hectare—a productivity gain of more than 100 percent—while reducing water and fertilizer use and lowering methane emissions.

Climate-Smart Agriculture Helps Feed More People in Senegal

Senegal is building a more resilient and productive food system that also helps mitigate climate change through the West Africa Agriculture Productivity Program (WAAPP). Scientists have developed seven new high-yielding, early maturing, and drought-resistant varieties of sorghum and pearl millet adapted to local growing conditions. On average, the new varieties yield 1.5 to 2 tons per hectare—significantly more than the 0.5 ton per hectare yields that are the norm from traditional varieties. The seeds have been distributed to farming cooperatives around the country, which have been charged with producing more seeds and selling them back at a price higher than the market standard. Farmers around the country are also taught climate-smart planting techniques

that use less water and fertilizer to improve their productivity in the face of irregular rainfall and droughts. Greater productivity and resilience, with a concurrent reduction in fertilizer use, is helping to deliver the triple win.

Climate-Smart Agriculture Cuts Emissions in Bangladesh

Through Global Agriculture and Food Security Program (GAFSP) funding, the World Bank is promoting an approach that incorporates the use of optimal and timely use of new rice seeds, new fertilizer, and the implementation of new water management (including the alternate wetting and drying (AWD) approach that saves water and offers other important benefits such as human disease control). The project funds "farmer field schools" to demonstrate the project's benefits to farmers in target villages. The AWD technique makes use of the cycle of draining and re-flooding of rice paddies, keeping an optimum water level at any particular time. It typically takes 2,000 liters of water to produce a kilogram of rice; however, AWD can reduce water use by 25 percent. AWD also helps reduce GHG emissions, specifically methane, by up to 50 percent. This project also supports reduced fertilizer use by promoting deep placement of fertilizer and precision application—leading to a significant drop in methane emissions. Used in combination with soil and water conservation, these practices deliver adaptation and mitigation benefits in crop, livestock systems and fisheries.

Partnering with scientists to achieve triple-win in coffee sector in Central America and Mexico

A GAFSP-financed project in Central America's coffee sector, supported by the IFC in partnership with scientists, the private sector, and farmers, is helping combat the devastating coffee rust disease *La Roya* by planting improved varieties in coffee plantations. In another program led by the private sector, the world's leading organic coffee producer, Keurig Green Mountain, partnered with the International Center for Tropical Agriculture (CIAT) scientists to help farmers diversify coffee-based production systems—while providing technical assistance to farmers. Some farmers have begun using income from their coffee harvests to expand into other enterprises (like fruits, vegetables, cocoa, livestock, and honey) and vice versa. Intercropping promoted through this collaboration has helped to boost incomes and fight hunger in the coffee lands while delivering adaptation and mitigation benefits in part of Nicaragua and in Chiapas state, Mexico. Diversified production systems have helped boost the resilience of farmer incomes throughout the year, while fruit trees provide shade, boosting resilience to drought and heat, and absorb carbon.

Farmers, the private sector and scientists partnered to reduce the incidence of inter-seasonal famine, boost resilience, and lower emissions through intercropping in coffee production systems in Nicaragua and Mexico.

Improving Livestock Productivity and Curbing Deforestation in the Brazilian Amazon

In Brazil, mitigation of emissions from the livestock sector has become the centerpiece of a national strategy to achieve voluntary targets for GHG mitigation. Brazil committed to reduce deforestation in the Amazon and the Cerrado, scale up no-till planting, and reduce nitrogen emissions from farming. Total pledges will reduce emissions by 700 million tons CO_2-eq by 2020 within ten years. The Brazilian Cooperation Agency program provides a credit line for loans to farmers to finance a range of mitigation practices to meet pledges—intensifying livestock production, restoring degraded grasslands, and integrating livestock and crop farming systems—that also strengthen resilience to drought. Cattle productivity has been growing since 2004 alongside impressive reduction in deforestation. This is also a triple win.

Climate Smart Profiles — A Tool to Help Guide Country Prioritization

One tool to systematically assess the opportunity for countries to simultaneously deliver higher agricultural productivity, improved resilience, and lower emissions are the CSA Country Profiles. Introduced initially in Latin America and now being extended to other regions, CSA Country Profiles can be an important mechanism to build awareness of country options, facilitate dialogue, and help prioritize investments to deliver on the triple win.[15] The profiles provide a climate lens through which to view the food system; they help to understand how economically-important food production can be affected by weather shocks and identify ways to improve productivity and adaptation potential while reducing emissions. All these enable quick comparisons of different interventions in different sectors, and serve as entry points for action.

CSA profiles have been completed or are ongoing in 18 countries in Latin America and the Caribbean, Sub-Saharan Africa, and South Asia. Scaling up the approach in partnership with other countries will help inform prioritization of investment in CSA.

Intercropping ranks high in terms of CSA smartness in Peru, Grenada, Kenya, and Argentina. Through diversification, it raises productivity, efficiency of soil and water use, and promotes resilience and carbon storage. In Grenada, intercropping cereals with legumes cuts fertilizer use and reduces nitrogen emissions.

The Country Profiles provide a visual overview of the degree of climate-smartness of the most important production systems in a country, identifying good

practices and potential for improvement. The Country Profiles present an index score of climate-smartness, used to rank a range of current practices on the scope for productivity gains, increased resilience and lowering emission for climate-smart practices (Figure 3). The scores comprise measures in six categories: weather, water, carbon, nitrogen, energy, and knowledge. In addition, the Country Profiles provide the national and regional policy context, and financing options. Production systems chosen in each profile are specific to the socioeconomic and cultural context of a country and are drawn up in consultation with farmers.

> **Improved shade coffee and tea systems** in El Salvador and Sri Lanka are climate smart. Higher quality of shade coffee helps meet requirements for certification in El Salvador, shade species are more resilient to drought, and nitrogen fixing trees provide shade and improve soil fertility. In Sri Lanka, improved productivity shade-grown tea reduces the need for irrigation, is more productive, and has a lower emissions footprint.

What do CSA Country Profiles reveal? Results from previous profiles exercises have identified practical and achievable interventions and investments in a number of countries. For example:

- Introduction of agroforestry and silvopastoral systems in coffee and mixed farming systems in Colombia, Kenya, Mexico, and Peru
- Introduction of shade and timber trees in pastures in Argentina, Colombia, Mexico, and Peru
- Intercropping in Argentina, Grenada, Kenya, and Peru
- Growing shade coffee and tea in El Salvador and Sri Lanka
- Rotating crops in bean and maize systems in Rwanda
- Intensifying cattle systems, and use of cattle dung as fertilizer in El Salvador
- Rehabilitating hurricane-damaged nutmeg fields in Grenada.

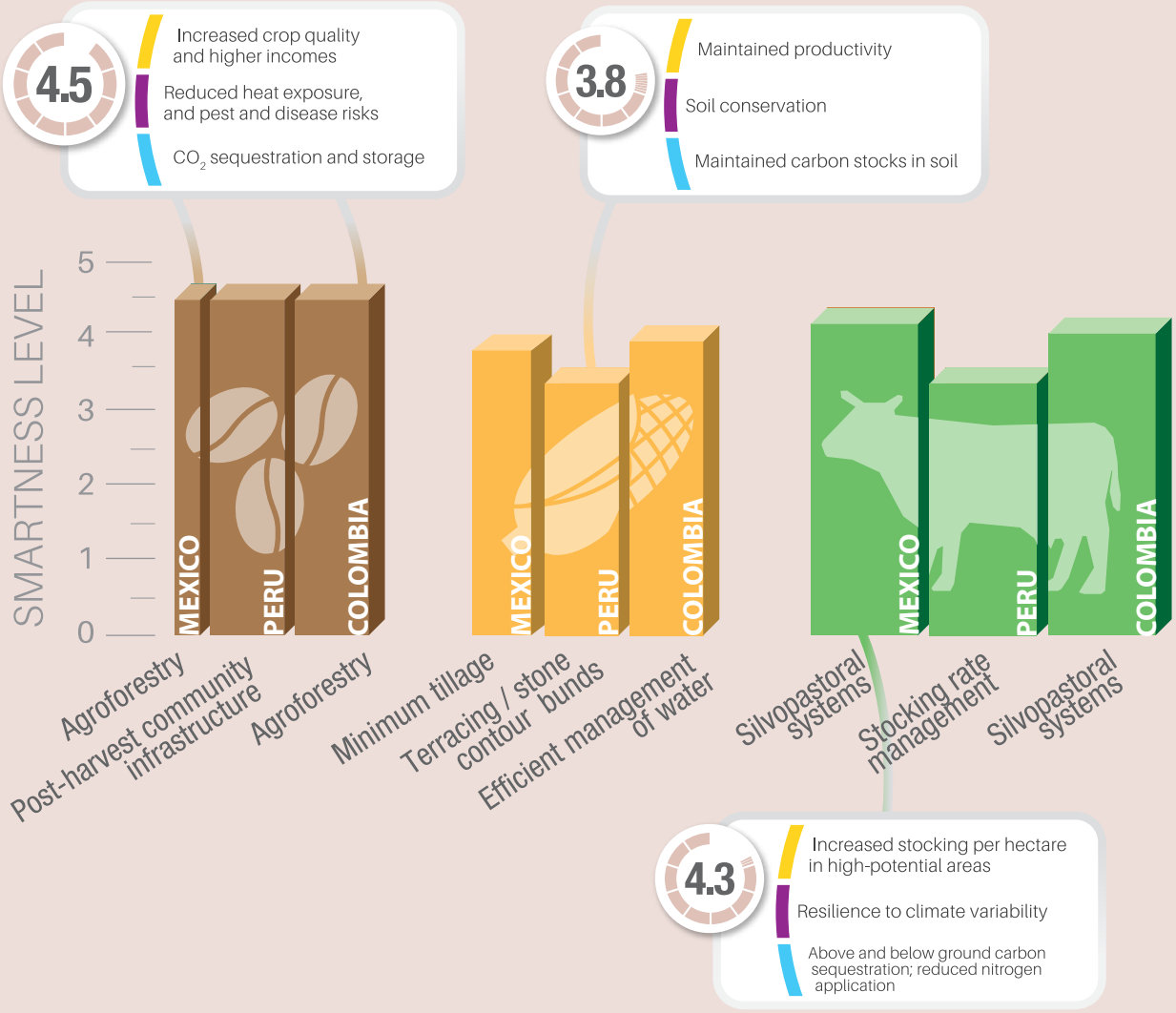
The Country Profiles provide decision makers with a baseline on CSA—a valuable tool to facilitate preparation of national action plans for CSA investments, strengthening institutions and formulating policy. While the Country Profiles do not include cost-benefit analysis or an assessment of barriers to the adoption of CSA practices and technologies, they provide a broad range of possibilities to potentially achieve the "triple win" within diverse farming systems and across socioeconomic settings and agroclimatic conditions. Some practices may simultaneously deliver higher productivity, improved resilience, and lower emissions at the farm level, while others, when combined, may deliver them at a landscape level.

Figure 3. Climate-Smart Agriculture Profiles for Policy Makers

Securing the triple win of CSA

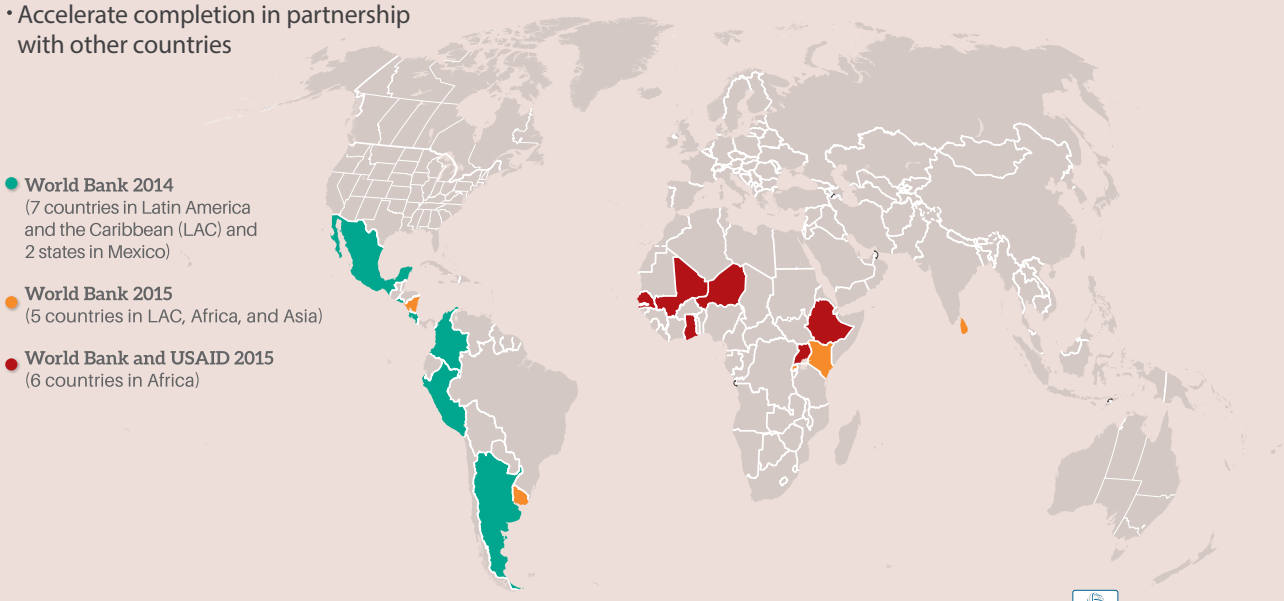
- Boost productivity
- Enhance resilience
- Cut greenhouse gases

Snapshot of climate-smart practices in 3 production systems in Colombia, Mexico, and Peru



CSA Profiles around the world

- 14 Profiles completed and 6 ongoing
- Accelerate completion in partnership with other countries



How to create a CSA Profile

1 Define national context

- International data sets (WB, FAO, etc.)
- National statistics
- International climate databases

2 Identify CSA technologies and practices

Surveys and interviews with technical experts and producer associations

3 Review institutions and policies

Stakeholder mapping: Interviews with key actors in Ministries, NGOs, producer associations

4 Inventory financing options

Stakeholder mapping: Interviews with key actors in Ministries, NGOs, producer associations

Stakeholder validation

More information:
http://climatechangeknowledgeportal.worldbank.org
http://dapa.ciat.cgiar.org/csa-profiles/

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How to Achieve Climate-Smartness? Role of Incentives, Knowledge, Science, and Finance

Without a clear value proposition for farmers and companies to make climate-smart investments and follow climate-smart behaviors it will be challenging for CSA to reach transformational scale. Fortunately, at the root of the majority of CSA interventions lies a focus on sustainable efficiency and thereby an inherent value proposition. For example, reduced use of fertilizers leads to reduced costs; an increased efficiency in livestock leads to greater returns for feed and labor; solar irrigation results in reduced energy costs; a reduction in postharvest losses and reduced retail/consumer wastage produces greater incomes, increased profits, and reduced food bills. Highlighting and demonstrating these gains to producers and businesses is an important and critical factor that has not previously been a focus of traditional agricultural productivity approaches. Farmers need to see how they can sustainably "make money, save money, or save time" before they are likely to change their behaviors, adopt new practices or invest in new technologies. As such, research and polices need to clearly demonstrate how CSA will benefit both people and planet. Where the individual value proposition is weaker, public incentives should align to incentivize farmers and companies to invest in CSA. It will not always be the case that adoption of CSA will result in short-term individual returns and so, due to the public good nature of the triple win, public resources should be aligned to catalyze action on CSA.

Incentives, knowledge, and policies

Realigning a variety of incentive policies currently in place can improve the climate smartness of the food system. A range of incentive policies are currently used by developed and developing countries: market and input price support and direct payments to

agriculture. For example, in Organisation for Economic Co-operation and Development (OECD) countries over half of the producer support estimate (PSE) is direct payments to agricultural producers, whereas in developing countries about 70 percent of the PSE is market price supports.[16] There is scope for using these policies to achieve improved climate-smart outcomes. As indicated earlier in this paper, there has already been adoption of climate-smart practices in many countries, and this can be accelerated with a better alignment of producer incentives.

Aligning market price support and input and production policies to achieve better climate outcomes. Price supports, inputs policies, and restricting land to the production of certain crops can limit crop diversification, induce economic inefficiency, compromise productivity and resilience (with water and soil degradation), and lead to high GHG emissions. Design of market price support polices should consider the climate resilience and emission intensity of the likely production patterns they will induce. We need to accelerate the alignment of farm-level incentives with better climate outcomes and significantly more effort is needed in this regard to enable the world to build a more climate-smart food system.

Aligning direct farm payments to better climate outcomes. Making direct payments to farmers conditional on adoption of climate adaptation and mitigation practices will lead to better climate outcomes. This is already happening, as 30 percent of direct farm payments under the EU Common Agricultural Policy require adoption of environmentally beneficial farming practices.

Incentives to reduce deforestation driven by agriculture require a systemic approach to achieve success at scale. In addition to the realignment of existing sectoral incentives, greater efforts are needed to target incentives from REDD+ and other similar approaches to reward agricultural producers for verified reductions in the pressure on deforestation or reductions in direct emissions through intensification of their agricultural production. This will require a shift away from an approach that seeks to manage a perceived trade-off between food and forests and towards a food system approach that focuses on maximizing synergies between forestry and agriculture. Where there is a risk that the success of intensification may lead to extensification, this must be managed specifically, but should not hamper efforts to operationalize a synergistic approach that will deliver multiple beneficial outcomes.

In some cases, barriers to adoption may be lack of knowledge rather than incentives. Information sharing, education, and training are critical for ensuring adoption of existing practices and technologies that can raise productivity and resilience, with positive mitigation co-benefits. Adoption has also often been limited by institutional, regulatory, and financial constraints. Addressing the constraints is essential to achieving the triple win. However, beyond existing technologies, new technologies that better deliver the triple win will need to be developed. While existing technologies are a good starting point and their broader application needs to be scaled up, new technologies must be developed to build a climate-smart food system and ensure the triple win.

Public and private finance

Increased amounts and types of private finance will be needed to enable farmers and companies to invest in CSA. Formal financing of the agricultural sector has always been problematic due to perceptions of heightened risk, low profitability, high disaggregation of farmers, and losses due to quality and waste. While delivering on the three outcomes, CSA fundamentally addresses a number of these traditional challenges. Farmers who increase their productivity become more profitable; farmers who increase their resilience and adapt to climate change present a better risk profile. The challenge is to educate and persuade banks to both be able to quantify these improvements and to identify those farmers who are implementing CSA. Equally, we must develop the opportunities to leverage the commercial relationships within the food system. With over 90 percent of risk and emissions lying at the production level in food supply chains, food processors and retailers must work with farmers to develop resilient supply chains that help both sides to reduce risk and emissions. The key to success lies in creating leveraged finance that will enable farmers to invest in their farms and play a more active role in established supply chains.

This new interdependence between farmers and companies is driving an improvement for farmers in terms of new financial opportunities. Through financial tools such as value chain finance, leveraged long-term supply contracts, and innovative, participatory outgrower schemes, the potential for increased formal financial flows to agriculture is increasing. Critically, the establishment of longer-term supply arrangements will enable medium-term finance to flow to farmers in markets where there is an almost total lack of current liquidity (often driven by a lack of deposits). This medium-term finance is vital to enable farmers to make longer-term investments into their farms and to adopt technology, the costs of which cannot be borne by traditional seasonal finance.

Increasing opportunities for financial innovation exist for agriculture. With the expansion of formal climate finance through such bodies as the Green Climate Fund and the dramatic expansion in the green bond market, new opportunities exist for agriculture to benefit from the delivery of beneficial climate outcomes. The potential to develop blended finance (for example, where climate finance is used to improve credit terms for farmers), commodity-related credit and price enhancements (such as deforestation free palm oil) have increased dramatically. Modern parametric approaches to risk quantification and monitoring have led to the development of insurance type products that have the ability to manage risk more efficiently, especially at the aggregated (for example, banks) level, and that can be used to reduce the cost of finance for farmers. Increasingly, countries are introducing risk financing approaches and products that will enable the catastrophic layer of loss from events such as floods and droughts to be managed by government and enable compensation to flow to farmers—for example, the Africa Risk Capacity initiative. The challenge for agricultural finance is to move away from a traditional, collateral-backed financing model to one where finance flows to equitable and sustainable farming systems

so that climate finance and policies can play a transformational role in achieving success through wider adoption of climate-smart approaches in the global food system.

Science

A renewed urgency, and international and national commitment, is needed to sustain climate-smart agricultural research to deliver needed science-based solutions. We need to act now given that developing improved technologies can take many years. It requires commitment to strengthen agricultural research systems, build partnerships, and engage the private sector to facilitate the uptake of innovation at local levels. Developing improved plant and livestock breeds more adapted to changing climates to meet rising food demand while at the same time reducing emissions needs significantly more investment in agricultural research. At the international level, we need renewed commitment to fund climate-smart agriculture research that will deliver science-based solutions and drive their adoption. At the national level we need countries to strengthen their own agricultural research systems and engage the private sector to facilitate the uptake of innovation and deliver action on the ground. Additionally, finance will need to flow to enable both farmers and companies to deliver CSA at scale and do so in an enabling environment that catalyzes and supports concerted action. Given the time it takes for technology to move from research labs to farmers' fields, those investments are needed now if we are to have the necessary tools in the next decade. This urgency is backed by a strong rationale for investing in triple-win solutions that help lower the investment costs for farmers and reduce barriers to technology adoption in the future.

A leading example of how this investment can deliver results at the global level is CGIAR, which is the leader in science-based innovation for climate-smart agriculture. The CGIAR's global system of 15 specialized science and research centers has generated breakthroughs that have improved agricultural productivity and ecosystem resilience, leading to significant impacts through the broad uptake of technologies and innovation. Millions of farmers now have access to improved varieties developed by the CGIAR Centers and their partners through the national agricultural research programs, including disease-resistant wheat, drought-tolerant maize, and flood-tolerant "scuba" rice to name just a few. Additionally, as a founding member of the Global Alliance for CSA (GACSA), a group that has pledged to deliver climate-smart innovations to half a billion farmers over 15 years, the CGIAR has generated an extensive evidence base of practical solutions and is amplifying their dissemination through GACSA. Significantly more funding for

HISTORY SHOWS INVESTMENT IN AGRICULTURE RESEARCH HAS A HIGH SOCIAL RATE OF RETURN

Rates of return to public investment in agricultural research and extension have been very high, averaging at least 40 percent (Alston et al. 2000). And the returns to investment in agriculture research on technologies that simultaneously raise productivity, increase climate resilience, and reduce GHG emissions are likely to be even higher; because the costs of climate change to the food system, which that research will help limit, are mounting. The volume and the efficiency of investment in agricultural science needs to increase if we are to achieve better climate outcomes.

CGIAR is needed going forward to facilitate climate-smart innovation of the scale necessary to enable the transition to a more climate-smart food system.

Building strong agricultural research systems at the national level. Strong and sustained support to agricultural R&D can have large payoffs as reflected in its significant contribution to impressive agricultural growth achieved in Brazil, China and India. More broadly, returns to investment in agricultural research have been high and the benefits will only rise as the losses from climate-induced crop and livestock systems failure increase. However, investment in agricultural research has been fairly uneven across countries and regions, especially in Sub-Saharan Africa, which accounts for only 5 percent of global public spending on agricultural research and development.[17] With increased attention to agriculture through the Africa Union's Comprehensive Africa Agriculture Development Programme (CAADP), agricultural R&D spending increased by more than one-third from 2000 to 2011, but over one-half of that spending has been centered in just five countries—Kenya, Nigeria, South Africa, Tanzania and Uganda.[18] Increased attention in national systems on developing and adapting improved technology for better climate outcomes is needed.

Raising the efficiency of public investment in agriculture research through long-term strengthening of the policy and institutional framework. Agricultural innovation processes require long-term political commitment, financial stability, human resources, and institutional strength—as demonstrated by Brazil, Uruguay, and other countries. In Uruguay, more than a decade of national focus on sustainable intensification across systems and value chains, underpinned by strategic investment in agricultural science and technology, has translated into continued growth in agricultural productivity, climate change adaptation, and GHG mitigation.

Uruguay has quadrupled its agricultural production within a decade while significantly reducing per unit GHG emission of food production. Investment in CSA research and a focused action agenda on policy, investment, and science to reap the benefits of CSA are paying off. Uruguay's National Agricultural Information System which provides oversight of a soil use planning scheme, has encouraged 96 percent of all crop producers whose landholdings exceed 100 hectares to adopt CSA approaches, including the adoption of crop rotations that boost yields, reduce erosion, and enhance soil fertility.

Bringing Solutions to Scale

As the world mobilizes investments from public and private sources to meet the SDGs, the nexus of food security, productivity, and climate change has to come into sharper focus. The momentum is also present—under the SDG framework, the international development community and many governments are reconfirming their commitment to ending hunger, achieving food security and improved nutrition and promoting sustainable agriculture. The world needs to harness the potential of the global food system to deliver solutions to the climate problem within and beyond agriculture. In today's context with a firm recognition of the need to make visible progress on making the food system more sustainable, the attainment of at least half of the SDGs rests upon the ability to ensure the food system is productive, resilient, and contributing to tackling climate change.[19]

The imperative for transformative action is clear. If we continue to manage the food system following a "business as usual" approach, it is extremely difficult to see how we will meet the requirement to produce 50 percent more food by 2030. With yields flattening, the demand for animal protein growing, the population increasing and incomes improving, and an increasing rate of land degradation, the headwinds against the food system reaching its critical goal are almost insurmountable. In the face of climate change and considering the negative impacts the food system currently has on the climate, there is no doubt that a new approach to managing the food system is desperately needed. Equally, it is clear that an incremental approach to the challenges will simply be "too little, too late" and that the biggest losers of failure to change will be the poor and especially the rural poor—the vast majority of whom are farmers.

From adversity we must seize opportunity. While the challenges appear to be mounting, the focus must be on the fact that development of a climate-smart food system will provide real opportunities for farmers, consumers, and the planet. CSA is fundamentally an approach centered on sustainability, efficiency, synergies, and equitable partnerships. Where there are competing objectives, it specifically seeks to manage those trade-offs in an explicit and integrated way. Importantly, we know that CSA is an achievable and deliverable approach that is already beginning to show results in a wide range of geographies and production systems.

To deliver we must focus on results and be aspirational. Given the clear metrics and timelines that exist around global food security and agriculture-related GHG emissions and the science that determines that action must be decisive and swift, we must focus on where the need is greatest and at scale. Our greatest efforts must be focused on those sectors and geographies where existing solutions can deliver immediate results on the triple win and on those emerging areas where we can blend CSA approaches with opportunities to sequester carbon or avoid emissions. Increasingly, we must focus on monitoring results that have until recently not been a focus for the agricultural sector but are critical to its survival and well-being (GHG emissions, soil health, animal productivity, nutritional content).

We must build the partnerships to enable action. The size of the challenge will necessitate the creation of new and dynamic partnerships that deliver action. Regional, national, and local groups of stakeholders must come together to scale activities, to share experiences and to pool their resources and knowledge. Successful and unsuccessful approaches must be documented and built upon, enabling actors to catalyze change and build robust science. At the international level, these efforts can be supported by initiatives such as GACSA and the Global Research Alliance (GRA), acting as a clearinghouse for knowledge and incubating strategic partnerships for country-level action.

Investment must flow today to create the science of tomorrow. While we do know of a large number of existing successful approaches that can deliver CSA, it is clear that we will need new solutions for the planet that we will face tomorrow. For example, we need fertilizers that are vastly more efficient in plant nutrition and simultaneously reduce emissions and negative environmental impacts. We need the plants and animals that are much better adapted to higher and more variable temperatures. We require plant systems that combine multicropping with an increase in productivity. In the face of clear planetary boundaries we must manage our natural resources with a much greater return on natural capital and reduced negative impact on the environment. The transformative solutions will come from a determined and focused investment in the science which will address these challenges that will deliver practical approaches that can be adopted at scale for a broad range of farming systems, but especially for smallholders.

Public policy must focus on delivering both private and public goods. Delivering global food security in the face of climate change is one of the greatest challenges facing the

planet, and increasingly public policy must seek to deliver on a number of different but aligned objectives with less resources. Both policy development and execution must be considered across a matrix of sectoral and public/private objectives. To achieve this we need to realize that while agriculture is the route to food security, there are multiple destinations—nutrition, environmental protection, natural resource efficiency, incomes and livelihoods for the majority of the world's poor—and that policies must be aligned to enable farmers to deliver. Equally, these policies must incentivize and support farmers to produce positive externalities for the public good, not simply support their creation of private goods.

Without finance and a clear value proposition, action will not flow at scale. Without access to finance, especially for medium-term investments, farmers and companies will be unable to act at scale. While initial action will be possible where CSA is based on resource efficiency, often gaining these efficiencies in the long term and capturing other returns will rely on medium-term investments. Availability of properly risk-adjusted and competitive financing will be critical to enable these investments, as will be the existence of stable and transparent legislation and existence of strong property rights. Additionally, farmers and companies will need to clearly see the potential financial returns before they will be prepared to invest, even if finance is freely available. Where that value proposition is weak but potential public good returns are high, public finance will be required to develop attractive financing mechanisms and returns for farmers and companies.

In order to have transformative impact, we need to scale up successes—urgently and widely—by bringing together the best science with the best business practices to achieve the CSA potential to achieve the triple win. A global effort is needed. The challenges we face affect all of humanity, not one region, or one sector, or one economic stratum. Whether big business, small farmer, or government policy maker, we all need to take responsibility for creating a food system that is climate-smart, people focused, and planet friendly.

Annex Table

What Do CSA Country Profiles Tell? — Practices Delivering the CSA Triple Win

Country	*CSA Practice*	*Productivity*	*Adaptation / Resilience*	*Mitigation*
Kenya, Mexico, Peru, Colombia	**Agroforestry** in crops, trees and livestock systems in Kenya; coffee systems in Mexico and Colombia; plantain systems in Peru	Diversification of livelihoods and increased income per unit area	Microclimate and water regulation, soil conservation	*All countries:* Enhanced carbon sinks
Colombia, Peru, Mexico, Argentina	**Silvopastoral** systems in cattle farming	Livelihoods diversification, increased stocking rates per hectare	Greater resilience of livestock production due to improved soil quality, microclimate regulation	*All countries:* Increased carbon sequestration
Peru, Grenada, Kenya, Argentina	**Intercropping** (maize with other crops, bean, quinoa, soybean, fruit, etc. in Peru; fruit trees and vegetables in Grenada; cereals/ legumes with beans, pigeon peas, cowpeas in Kenya; wheat with legumes in Argentina)	Increased crop diversification; in Kenya, productivity and efficiency of soil and water use; in Argentina, reduced yield loss due to sterility from high temperatures during flowering	Reduced climate risks, greater efficiency in water and soil use	*All countries:* Improved biomass, increased carbon sequestration; *Peru and Grenada:* reduced nitrogen emissions from fertilizer; *Argentina:* reduced yield gap
El Salvador, Sri Lanka	Improved **shade coffee** systems in El Salvador; **shade management in tea** production in Sri Lanka	Improved quality and quantity of yields (requirement for certification) in El Salvador and, in Sri Lanka, improved productivity and reduced irrigation needs	Selection and maintenance of shade species improves resilience to drought, climatic variability and disease (El Salvador); improved soil moisture retention	*All countries*: Tree cover maintained or increased; *El Salvador:* incorporation of nitrogen-fixing species
El Salvador	**Diversification**, crop switching in coffee production	New sources of income from production of cocoa and fruits	Alternatives to coffee in areas affected by rising temperatures and spread of disease	Maintained productive tree cover in areas no longer suitable for coffee
Grenada	**Rehabilitation** of hurricane-damaged nutmeg fields	Productive use of otherwise marginal uplands, high-quality products for export	Watersheds protection in upland areas	Carbon storage through increased tree cover and soil conservation
El Salvador	**Semi-stabled cattle**, with cut-and-carry pasture systems	Reduced expenditure on feed and food supplements	Increased resilience to drought and rising cost of cattle feed	Soil conservation through reduced grazing on steep slopes
El Salvador	**Cattle dung** processing	Compost and fuel by-products	Improved hygiene contributes to control of pests and diseases	Reduced methane emissions, reduced application of nitrogen-based fertilizers

Country	*CSA Practice*	*Productivity*	*Adaptation / Resilience*	*Mitigation*
Mexico	**Cover crops** in maize production	Less need for inputs, which reduces costs Higher productivity from increased soil fertility	Water infiltration increased, which reduces risks of floods	Reduced nitrogen fertilizer use lowering emissions
Mexico	**Minimum tillage** in maize production	Increased productivity due to higher content of nutrient in soils	Increased water retention reduces crop losses due to drought	Promoted carbon storage in soil Reduced energy needs for irrigation
Sri Lanka	**Contour planting** in maize production	Reduces input costs related to irrigation and fertilizers, while increasing productivity	Ditches and other contour practices minimize surface runoff and improve the soil's water-retention capacity	Improved soil quality reduces need for synthetic fertilizers and reduces associated GHG emissions
Argentina	**Biofertilizers** in multicrop systems	Improved soil fertility favors crop productivity	Improves soil organic carbon and soil nutrients and can help in disease biocontrol	Reduces the need for chemical fertilizers that generally contribute high GHG emissions
Sri Lanka	Short and ultra-short duration **varieties in rice systems**	More stable and less variable yields, with potential income implications	More suitable for short and low rainfall seasons; reduces yield loss due to little water during flowering stage	Improved emissions intensity due to productivity increases
Rwanda	**Crop rotation** in bean and maize systems	Reduces the incidence of crop diseases, smarter use of nutrients and nitrogen fertilizer	Improved soil structure and lower emissions due to lower need for fertilizer	Lowering production costs while increasing productivity

Sources: (1) World Bank; CIAT; CATIE. 2014. Climate-Smart Agriculture Country Profiles for Latin America Series; (2) World Bank; CIAT; CATIE. 2015. Climate-Smart Agriculture Country Profiles for Sri Lanka, Kenya and Rwanda.

Note: Selected examples. The full range of practices is presented in CSA Country Profiles. Analysis for Sri Lanka, Rwanda, and Kenya is ongoing and results are subject to change.

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שיווק פירות איכות טריים

1818 H Street, NW
Washington, DC 20433 USA
Telephone: 202-473-1000
Internet: www.worldbank.org/agriculture
www.worldbank.org/foodsecurity
Twitter: @WBG_Agriculture