Bringing the Concept of Climate-Smart Agriculture to Life

Insights from CSA Country Profiles across Africa, Asia, and Latin America

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Cover design: Fernanda Rubiano

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The CSA Country Profile methodology was first prepared in 2014 under the leadership of Svetlana Edmeades and Ana Bucher (World Bank), Caitlin Corner-Dolloff and Andy Jarvis (CIAT/CCAFS), and Claudia Bouroncle (Tropical Agricultural Research and Higher Education Center - CATIE) and with a team comprised of Andreea Nowak (CIAT), Miguel Lizarazo (CIAT), Pablo Imbach (CATIE), Andrew Halliday (CATIE), Beatriz Zavariz-Romero (CIAT), Rauf Prasodjo (CIAT), María Baca (CIAT), Claudia Medellín (CATIE), Karolina Argote (CIAT), Chelsea Cervantes De Blois (CIAT), Juan Carlos Zamora (CATIE), and Bastiaan Louman (CATIE). It was subsequently revisited in 2015 and 2017 by Andreea Nowak, Caitlin Corner-Dolloff, Miguel Lizarazo, Andy Jarvis, Evan Girvetz, Godefroy Grosjean, Felicitas Roehrig, Jennifer Twyman, Julian Ramirez, Carlos Navarro, Jaime Tarapues, Steve Prager, Carlos Eduardo Gonzalez (CIAT/CCAFS), Tobias Baedeker, Minna Konnonen, Tim Searchinger (World Bank), Charles Spillane, Colm Duffy and Una Murray (National University Ireland Galway). Additional support for CSA Country Profile development was provided by the United States Agency for International Development Bureau for Food Security (USAID BFS) and the Food and Agriculture Organization (FAO) of the United Nations. Data coding and management for this report was also provided by Fridah Nyakundi and Rachel Mburu.

The Climate-Smart Agriculture (CSA) Country Profile Series assesses climate change challenges and solutions in the agricultural sectors of more than 30 countries across Africa, Asia, and Latin America and the Caribbean (LAC). This report introduces the first analysis of a new dataset drawn from these profiles, aggregating bottom-up results from individual expert assessments of CSA technologies. It offers the most complete overview to date of technologies considered climate-smart around the world. The emerging insights shed light on technologies in different locations and farming systems, their strengths and weaknesses across different dimensions of climate-smartness, and their specific barriers to adoption. As a result, a more concrete and specific picture of CSA emerges that could help demystify the concept, reveal synergies between the three CSA pillars (productivity, adaptation, and mitigation), and allow for more targeted technology deployment and scale-up.

Top 10 CSA Insights

1 Technologies considered climate-smart are highly diverse. The universe of potential CSA technologies presented here is vast, with more than 1,700 unique combinations of production systems, regions, and technologies assessed for their smartness across key indicators like yield, water use efficiency, impact on carbon stocks and others. This report covers almost 300 distinct production systems across 33 countries. There is considerable opportunity to tailor CSA to specific farmers' needs.

2 A convergence is growing among stakeholders on where and how CSA can make the biggest difference. While CSA is diverse, just five technology clusters (water management, crop tolerance to stress, intercropping, organic inputs, and conservation agriculture) account for almost 50 percent of all CSA technologies identified by experts as climate-smart across the 33 countries. The top 15 technology clusters represent almost 80 percent of all identified technologies.

3 Technologies considered climate-smart by experts vary considerably across regions, reflecting the context-specificity of opportunities, constraints, vulnerabilities, and agricultural sector characteristics around the world. For example, Africa's primary focus is land restoration strategies, while in Asia, agricultural diversification strategies are considered key. These differences suggest that CSA has already been heavily tested and adapted to local and regional settings.

4 The "smartness" of a given CSA technology is dependent on context, and can vary considerably between different production systems and locations. The spread between the highest and lowest smartness score for a given CSA technology in this global analysis is 6.34 points (on a -10 to +10 point scale). Key factors that influence success of CSA technologies in a system must be assessed before developing priorities.

5 CSA technologies with the highest smartness scores are not always widely prioritized by experts and widely identified technologies do not always hold the highest smartness scores. For example, within maize (corn) systems globally, experts identified boundary planting as climate-smart on just three occasions (representing 1.6 percent of all technologies for that crop), despite an average smartness score of 7.10. Crop tolerance to stress represented over 14 percent of all technologies, but received an average smartness score of only 3.31.

6 CSA appears to coincide with common-sense agriculture. Income and profit indicators were rated almost uniformly positive for all CSA technologies by experts. Technologies considered climate-smart generally scored highest in productivity and adaptation CSA pillars, emphasizing the importance of measures of yield and income in encouraging adoption of technologies and the general prioritization of productivity over other pillars.

7 Most technologies considered climate-smart demonstrate synergies between productivity, adaptation, and mitigation pillars, revealing opportunities for co-benefits and potential "triple-wins." Experts only identified trade-offs for a small number of technology clusters, whereas five technology clusters—tree management, improved pastures, silvopasture, conservation agriculture, and water management—are included in the top 10 smartest technologies for all three pillars.

8 CSA technologies in Country Profiles focus disproportionately on cropping systems, especially cereal crops. More than two-thirds of all technologies in this global synthesis apply to food crops such as maize, wheat, and rice or cash crops (perennials). Only 18 percent of technologies considered climate-smart were analyzed for livestock systems and just 2 percent for aquaculture systems. This is, in part, the product of experts consulted for Country Profiles specializing disproportionately on crop and cereal systems.

9 Capacity needs in the form of training and information was identified as the single largest barrier to CSA adoption across all regions, affecting almost 90 percent of all interventions. Investments in capacity building (for farmers, experts, and decision makers alike) and knowledge dissemination (through public extension services, universities and academia, or the private sector) are critical for ensuring the widespread adoption of CSA, particularly to enable the vital but complex implementation of integrated measures.

10 There is no CSA "silver bullet" and the smartness of a system depends on more than the technologies deployed at plot level. A key limitation of Country Profiles is their focus on singular interventions, rather than integrated packages of technologies. Country Profiles also focus on on-farm technologies as opposed to broader value chains or services. The next chapter in the CSA story will be to move beyond a "practice" lens, exploiting the potential for transformational change via locally appropriate bundles of technologies and services, and to integrate this information into the development of Climate Smart Investment Plans at the country level.

II. Introduction

Agriculture is a risky business, even in the best of conditions. This situation is especially true in much of the developing world, where farmers rely heavily on rainfall, plant in degraded soils, and often lack access to high-quality inputs or markets. These same places are where the impacts of climate change will be the most hard felt. Climate change and associated extreme weather events will disrupt production and reduce agricultural yields across much of the developing world, placing new and greater stresses on natural resources required for food production.

Agriculture is also a major contributor to climate change. Soil disruption, livestock methane emissions, deforestation, carbon-heavy processing, and global supply chains make agriculture one of the largest sectoral emitters of greenhouse gases (GHGs). These factors, combined with the effects of population growth, changing diets, rapid urbanization, and other trends, will result in farmers, pastoralists, and fishers everywhere facing unprecedented challenges in feeding themselves and the world.

Since the concept first emerged in 2009, CSA has helped to increase awareness of the two-way relationship between agriculture and climate change, drive the development of more sophisticated tools for the assessment of climate-smart technologies, and mobilize a coalition of organizations and institutions dedicated to promoting CSA in a variety of settings around the world. The World Bank Group, the Food and Agriculture Organization (FAO) of the United Nations, and the Consortium of International Agricultural Research Centers (CGIAR) are especially committed to scaling up CSA, helping farmers produce more, build resilience, and pursue reduced GHG emissions.

Over the past decade, CSA has been a powerful organizing principle, bringing distinct stakeholders together in unprecedented ways. CSA and its advocates have helped to place agriculture squarely on the negotiating table at the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). At COP23 in Bonn, a historic decision was made for the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation to jointly address issues related to agriculture. This event represented the first time that agriculture was identified as an implementation target in the Convention's more-than 25-year history.

A central component of this new commitment is pursuing methods and approaches for assessing co-benefits among productivity, adaptation, and mitigation for agricultural technologies. This report answers important questions regarding CSA around the world today, further demystifying CSA, and highlighting factors that may influence its adoption and up-scaling.

Climate-Smart Agriculture

The CSA concept reflects an ambition to improve the integration of agricultural development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA technologies sustainably increase productivity, enhance resilience, and reduce or remove GHGs. However, implementation of technologies requires planning to address trade-offs and synergies (co-benefits and "triple-wins") between the three CSA pillars: productivity, adaptation, and mitigation.

III. CSA Country Profiles

The global synthesis presented here is drawn from CSA Country Profiles. The development of these profiles is based on a participatory, rapid, and cost-effective approach to identifying entry points, opportunities, and challenges related to CSA at the country level. The first profiles were provided for 10 countries in LAC in 2014 by the World Bank, International Center for Tropical Agriculture, the Tropical Agricultural Research and Higher Education Center, and the CGIAR research program on Climate Change, Agriculture and Food Security—together with national governments and national experts. In the following years, 23 subsequent profiles were developed with additional support from the United Kingdom's Department for International Development, the United States Agency for International Development Bureau for Food Security, and the Food and Agriculture Organization of the United Nations.

While Country Profiles are holistic in their scope (figure 1), at their core is an empirical assessment of potential CSA technologies. These assessments are built on structured expert consultation rather than on direct observation or monitoring and evaluation of technology implementation. Approximately 40–50 Country-level experts assign scores (assessments) to CSA indicators related to productivity, adaptation, and mitigation for select technologies in key production systems and agro-ecological zones. Experts were identified by national consultants and partner organizations familiar with the landscape of agricultural actors in each country, with an effort to diversify expertise across a broad range of production systems. These assessments indicate the change that experts expect in a specific production system if an identified technology were to be applied. The assessments provided in the profiles are built on expert perception, based on intimate knowledge of local production systems, agricultural practices, and challenges and opportunities for implementing and scaling CSA interventions. Still, the findings presented here rely heavily on the composition of the expert group assembled and may not always be fully reflective of the broader agricultural system.

Case in Point—Country Ownership of CSA

Stakeholder consultation and country ownership are central to linking CSA Country Profiles to broader policy goals, and scaling CSA deployment. In Tanzania, for example, the government took strong ownership over the profile development process, establishing a dedicated CSA Profile Task Force. The task force, chaired by the Ministry of Agriculture, Fisheries, and Livestock, helped to ensure that the profile was one of the key resources used by the Government of Tanzania to inform the scaling up of climate-smart technologies in the country, while remaining in line with existing national priorities.

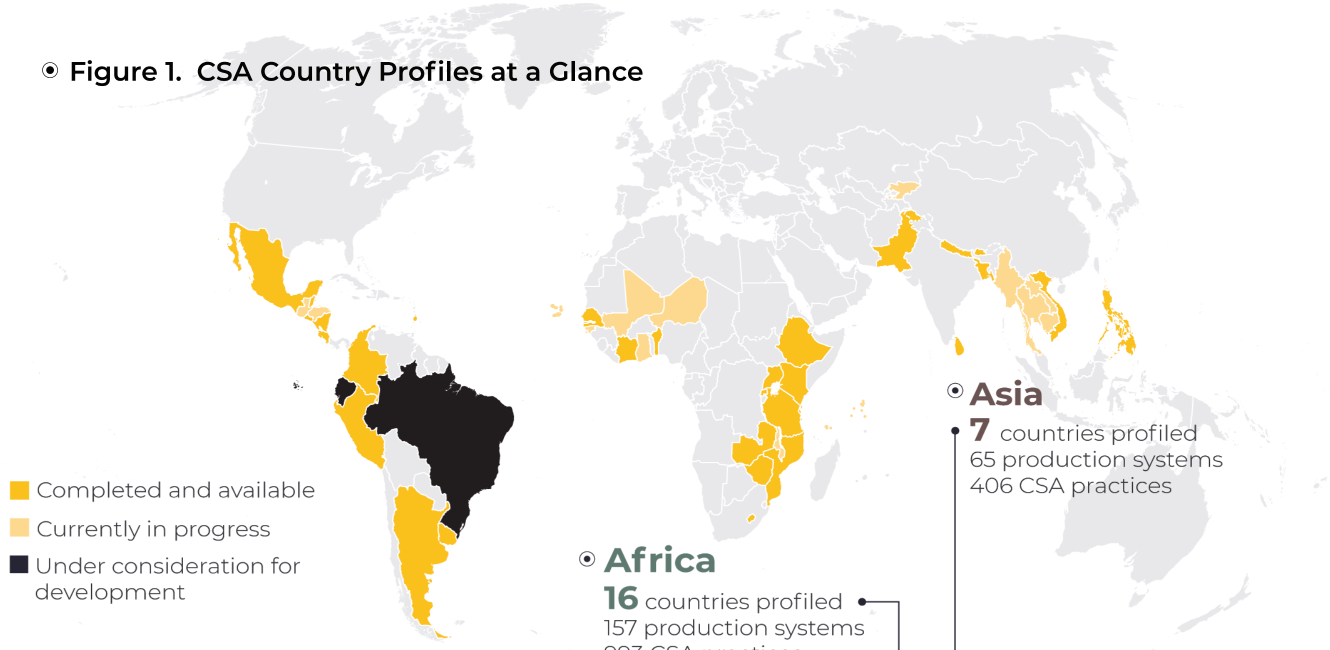
"Pakistan is a developing nation and [among the] most vulnerable communities to Climate Change in the region. I believe active participation from the public sector in developing the CSA Country Profile has shown commitment at the policy level and it will influence policy and planning [from the beginning]."

—**Aamer Hayat Bhandara,** Farmer, District Council Member (Pakpattan), Pakistan

"The CSA Profiles are innovative in how they present highly complex information on CSA in an easily digestible and visually appealing format and allow for benchmarking and comparison across countries. The CSA Profiles have already underpinned several World Bank investments and have paved the way for future initiatives linking agriculture and climate change agendas!"

—**Svetlana Edmeades,** Senior Agriculture Economist, World Bank

Figure 1. CSA Country Profiles at a Glance



Country profile key elements

National agricultural context

Economic dimension: Agricultural context, value of agricultural exports & imports, etc.

Social dimension: Poverty, agricultural jobs & incomes, gender inequality, food & nutrition security, etc.

Agri-environmental dimension: Land use, agricultural input use, GHG emissions, etc.

Climate change and agriculture

Projected changes in climate: Estimated changes in mean annual temperature and total precipitation

Economic impacts of climate change: Potential changes in net trade, yields, crop area, and livestock numbers under different scenarios

CSA practices and technologies

List of CSA interventions: By production systems & agro-ecological zones (5-10 production systems, 3-5 practices each)

Characteristics of CSA interventions: Farm scale, adoption rates, barriers

Climate-smartness assessment: Climate-smartness scores across CSA pillars

Enabling environment for CSA

Institutions for CSA: CSA-related stakeholders, mandates & actions

Policies for CSA: State of policy action in support of CSA goals

Finance in CSA: Current and potential funding streams available for CSA

Smartness score

Productivity

Yield
1. Yields
2. Post-harvest loss

Income
3.Income/profit

Adaptation

Water
4. Agricultural water availability
5. Water use efficiency

Soil
6. Soil disturbance (health)

Information
7. Climate risk management capacity
8. Agricultural diversification

Gender
9. Labor intensity for women in agriculture

Mitigation

Energy
10. Energy use from fossil fuels

Carbon
11. Above ground biomass
12. Below ground biomass
13. Soil carbon stock
14. Methane emission from livestock

Nitrogen
15. Nutrient use efficiency

Experts assign scores from -10 to +10 to each of these indicators

The final climate-smartness score is an average of all CSA indicators (e.g, 4.10)

Source: Nowak et al. (forthcoming)

IV. Global Synthesis and CSA Trends:

Demystifying CSA

The standard approach within CSA Country Profiles allows the combined data to be used to examine trends on a global or regional scale. Country Profiles and the smartness scores enable practitioners and decision makers to compare very complex processes across countries and better understand the "baseline" state of climate sustainability in agricultural systems. While the 33 countries for which profiles have been developed are neither exhaustive nor representative, the aggregated data between profiles represent an unprecedented snapshot of the state of CSA around the world, across a diverse range of geographies, agro-ecologies, and sociopolitical contexts. To date, across all profiles, more than 1,700 combinations of CSA technologies, cropping systems, and geographic locations have been analyzed and assigned a "smartness" score by local experts. This analysis covers approximately 17 percent of all GHG emissions from agricultural systems, and represents 16 percent of international livestock production and almost 20 percent of global cereal production in dollar terms. This global evidence base covers 290 production systems and has involved more than 1,500 expert consultations. Here we document 10 insights about the state of CSA emerging from this global synthesis.

Insight 1

Technologies considered climate-smart are highly diverse. Considerable opportunity exists for tailoring CSA to specific farmers' needs.

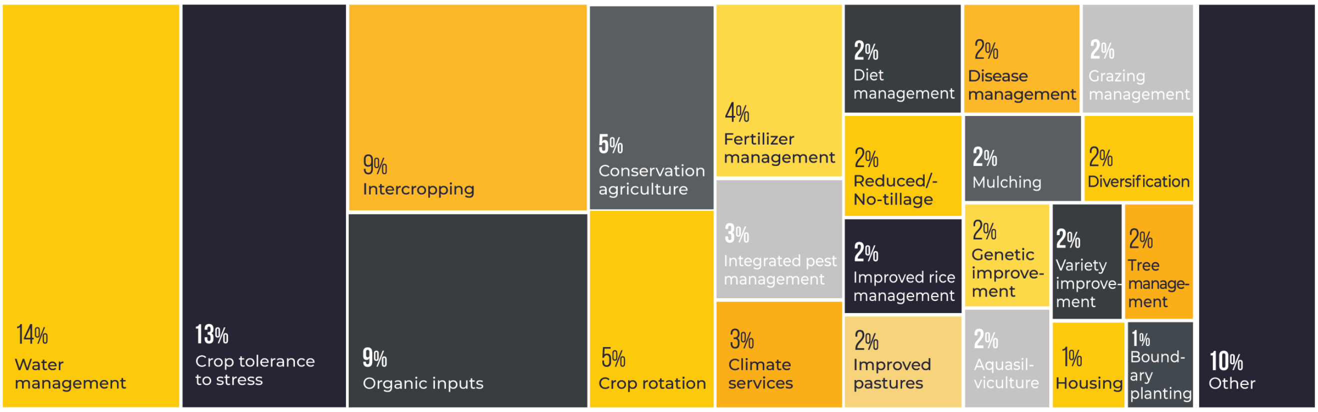
The universe of potential CSA technologies is expansive. Across this global analysis, 44 separate clusters (see Annex 1) of CSA technologies were identified, ranging from water management to crop rotation, improved pastures to tree boundary planting, and many others (figure 2).

Each technology cluster hosts a variety of sub-technologies. For example, water management includes drip irrigation, contouring, and terracing (for example, bunds, furrows, ditches, ridges, and half-moons), and rainwater harvesting. Meanwhile, improved pastures and grazing management includes shifts to "zero-grazing" systems, the use of feed supplements, changing stocking rates, planting fodder crops, rotational grazing, and improved management of pasture fertilizers, among other strategies. In total, CSA Country Profiles capture hundreds of unique CSA opportunities being implemented across diverse production systems and regions, demonstrating extraordinary potential for technology transfer, adaptation, and lessons learned.

"The CSA profile has helped agriculture stakeholders in the country to identify business opportunities in the different agricultural value chains. This is demonstrated through increase of involvement of partners such CSA value chains in the SAGCOT Region."

—**Ms. Shakwaanande Natai,** Head of Environment Management Unit, Tanzania Ministry of Agriculture

Figure 2. Frequency of Technologies Considered Climate-Smart by Cluster (global)



Insight 2

There is a growing convergence on where and how CSA can make the biggest difference. Several technologies are frequently identified as climate-smart and are highly scored globally.

While CSA is diverse in the sheer number of technologies, crops, and regions that it spans, experts consistently identify several technology clusters as climate-smart or highly scored. Just five technology clusters account for nearly 50 percent of all technologies considered climate-smart in this global synthesis: water management, crop tolerance to stress, intercropping, organic inputs, and conservation agriculture (figure 3). The top 15 technology clusters, which include technologies such as integrated pest management, reduced or no-tillage, and diversification, represent almost 80 percent of all CSA technologies globally. This may be the product of experts being influenced by the growing body of CSA literature related to these technologies.

This same concentration of technology clusters considered climate-smart exists within crops and production systems as well (figure 4). This situation is especially true for global rice production, where just three technology clusters account for more than 50 percent of all CSA technologies applied to that crop: crop tolerance to stress, integrated rice management, and water management.

Globally, the clusters with the highest smartness scores are silvopasture (the use of trees in pasture land) (6.49), conservation agriculture (5.56), cover crops (5.43), water management (4.95), improved pastures (4.91), and biogas (4.80) (figure 5). These global trends hold several regional variations. For example, while silvopasture and conservation agriculture are considered highly climate-smart across all regions, aquasilviculture ranks highly only in Asia. Mulching is a CSA technology cluster ranked highly in Africa and LAC, but is not frequently identified in Asia.

Figure 3. Frequency of Technology Clusters Considered Climate-Smart (global)

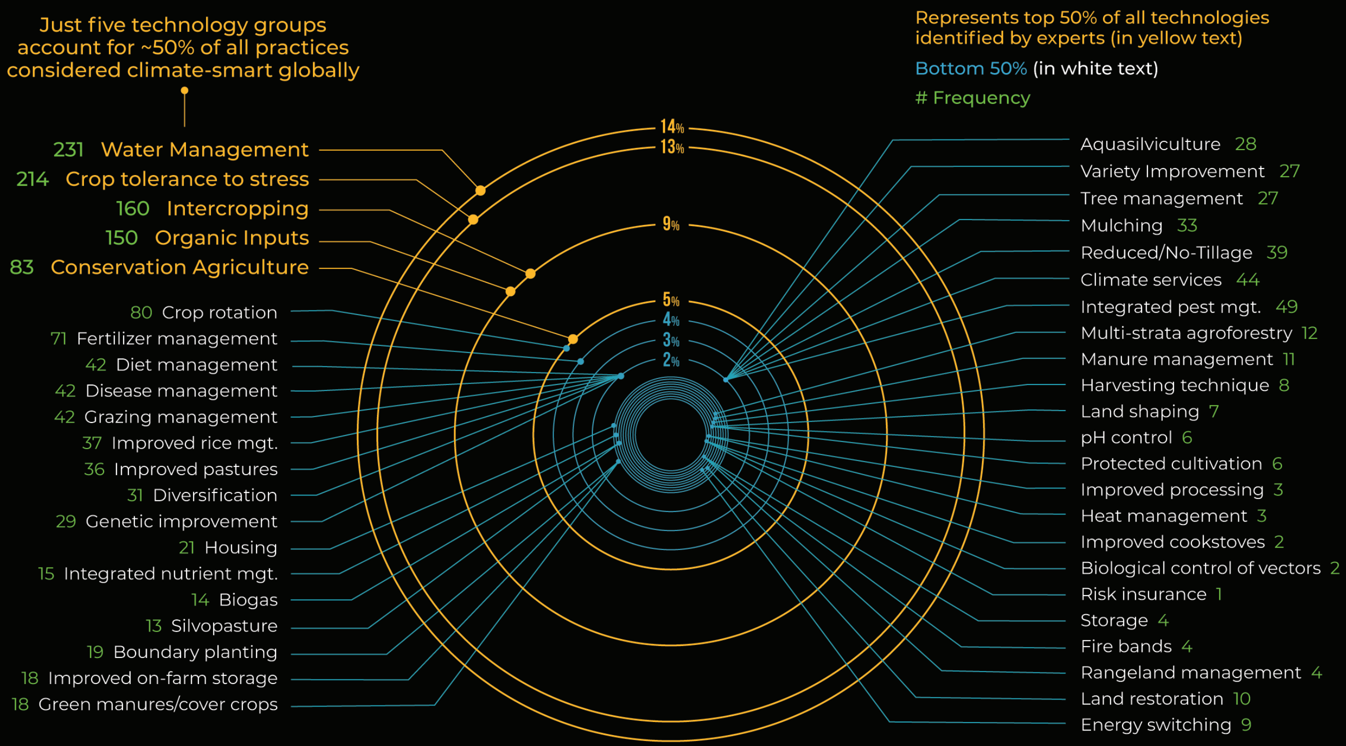
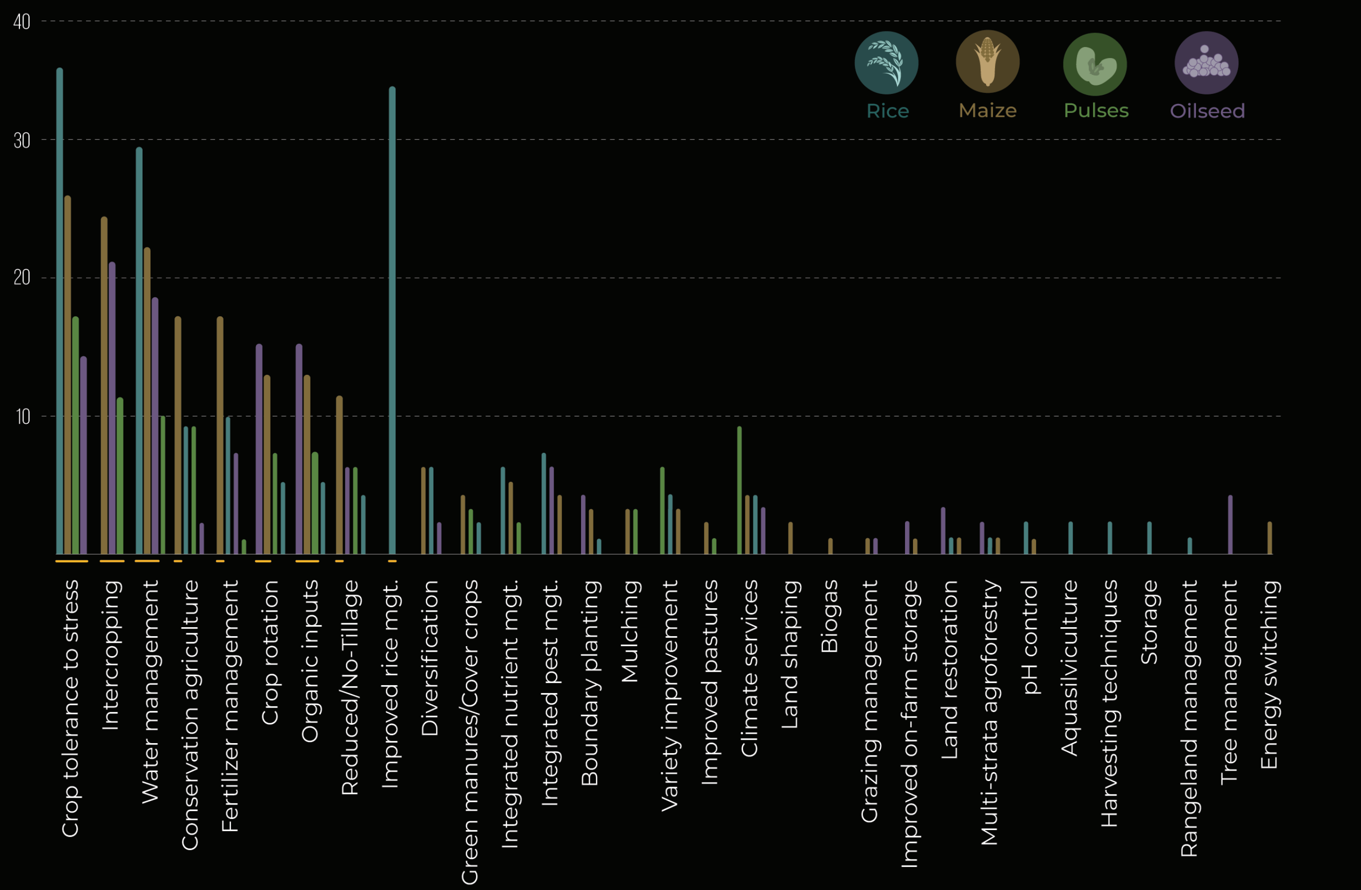
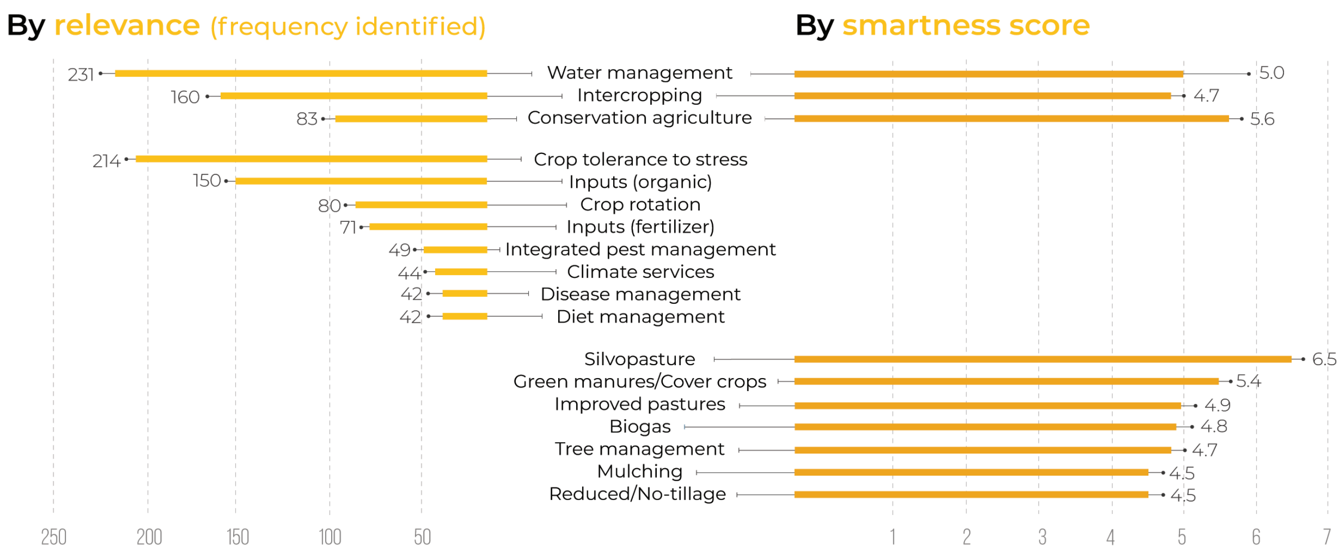


Figure 4. Frequency of Technology Clusters Considered Climate-Smart by Select Crops (global)



⦿ Figure 5. Top 10 Climate-Smart Technology Clusters (global)



Insight 3

Technologies considered climate-smart vary considerably across regions, reflecting the context-specificity of opportunities, constraints, and agricultural sector characteristics around the world.

Two of the top 10 smartest technology clusters—conservation agriculture and water management—are common across the Africa, Asia, and LAC regions. Still, technologies considered climate-smart vary considerably between regions (figure 6). For example, CSA Country Profiles reveal the following characteristics for Africa:

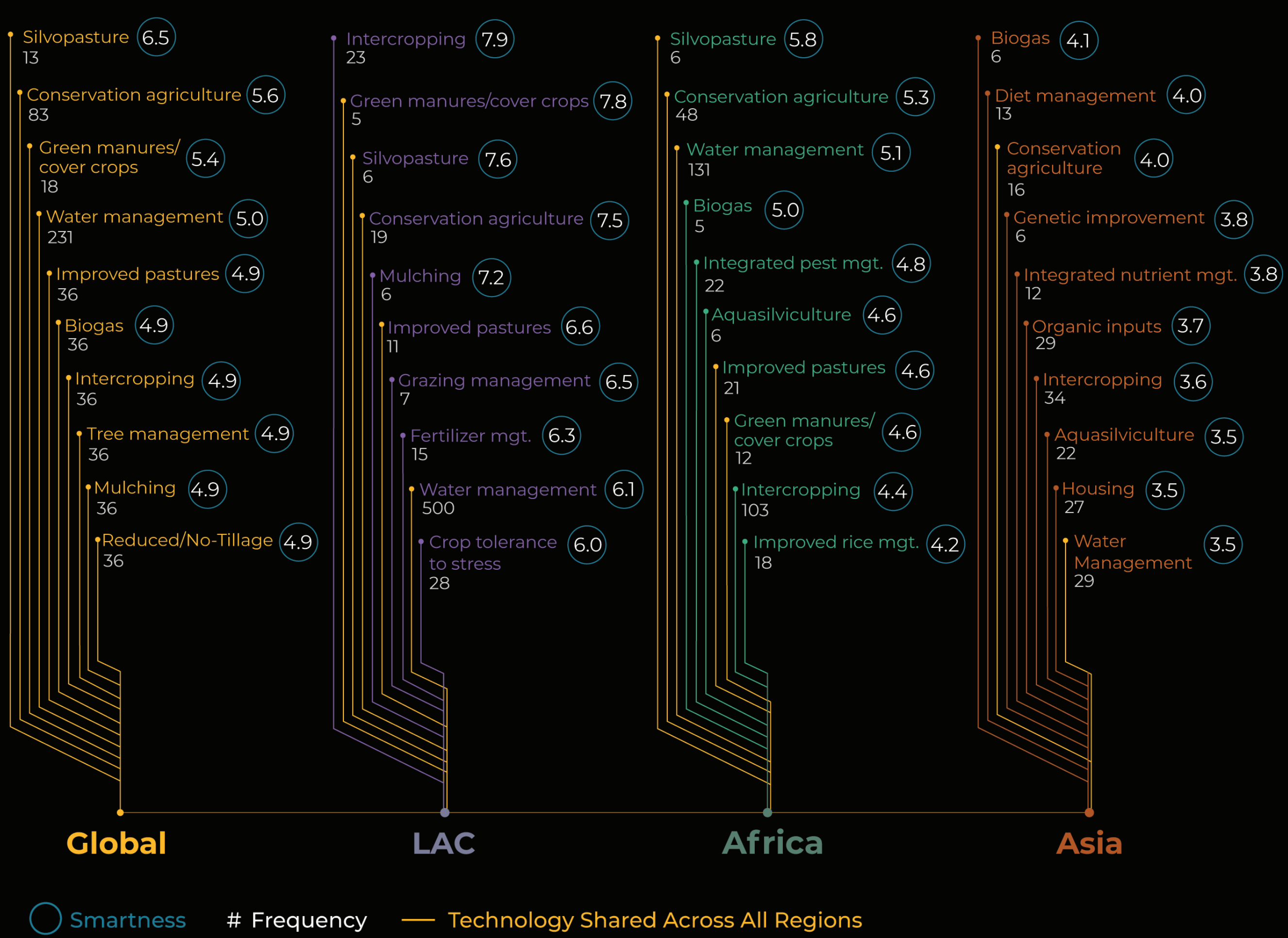
- Contouring, agroforestry, and other land management or land reclamation technologies are more common than in other regions.
- Disease management and livestock genetic improvement are most commonly identified in African nations.
- Risk management technologies (representing less than 3 percent of all technologies considered climate-smart globally) are more commonly identified—especially climate services.

Asia, meanwhile, hosts a high number of agricultural diversification strategies as well as many interventions that are focused on aquaculture and fisheries. Diversification as a CSA strategy was commonly identified only in Asia, and less so in Africa and LAC. Technologies considered climate-smart in LAC and Asia focus more heavily on cash crops than in Africa. Energy switching and improved cookstoves are nearly exclusive to LAC, while land restoration practices are largely absent in this region. In short, CSA is highly sensitive to local conditions, and the concept is being thoroughly verified by the prevailing conditions in each region (see regional dashboards).

Case in Point— Aquasilviculture in Asia

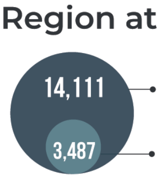
Aquasilviculture is a technology cluster considered climate-smart almost exclusively in Asia. In southern Bangladesh, many rural families are adopting small ponds, or "ghers", for prawn and fish production. These ghers are dug with wide embankments offering resilience against flood and cyclone damage, and providing an elevated platform on which to grow vegetables and other crops. This aquasilviculture technology has expanded greatly in the region thanks to training programs and rigorous documentation of investment returns. Private and government banks have begun investing widely in gher excavations given their relatively low risk and profitable returns.

Figure 6. Top 10 Smartest CSA Technology Clusters by Region (n>5)



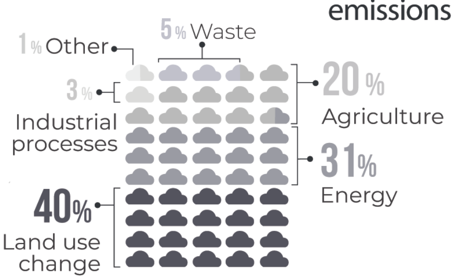
Sub-Saharan Africa

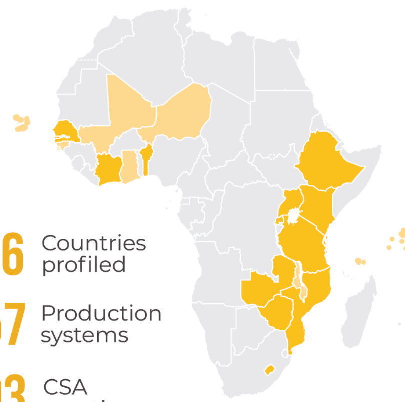
Region at a glance



Total emissions
Mt CO2 eq

Sectoral emissions





16 Countries profiled

157 Production systems

993 CSA practices

CSA Profile Footprint

Share of regional:

Crop Area 43%

Cash Crop Area 51%

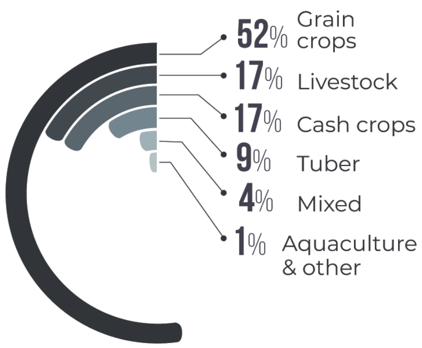
Agricultural Emissions 43%

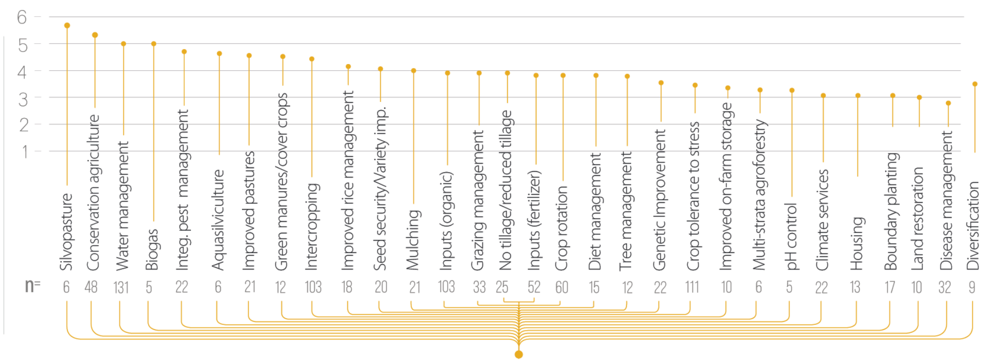
Cereal Production ($) 40%

Livestock Production ($) 37%

CSA trends

CSA frequency by commodity type

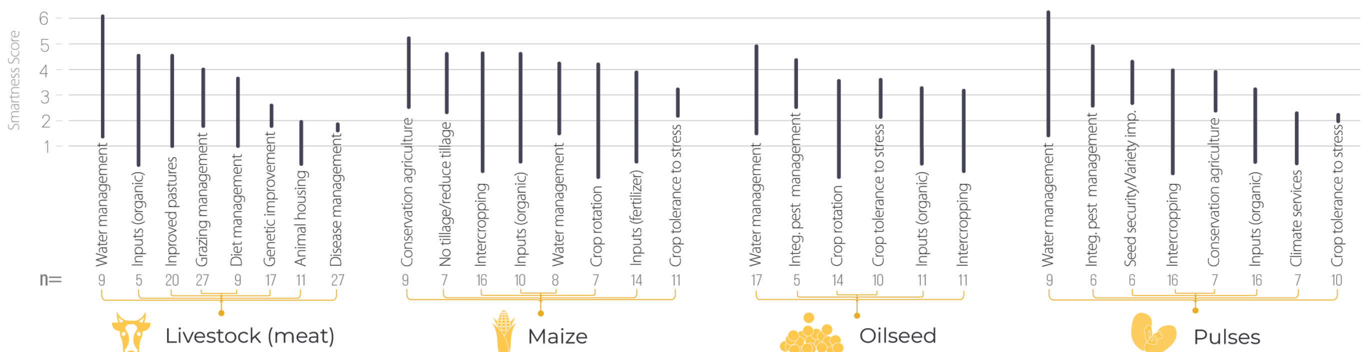




CSA smartness and frequency by technology cluster (all crops, all countries)

CSA in major production systems

(top-scoring technologies in commonly prioritized production systems)



Barriers and Institutions

Barriers to CSA adoption

(percentage of technologies affected by barrier according to experts)

88% Training/ information

39% Policy/ institutional

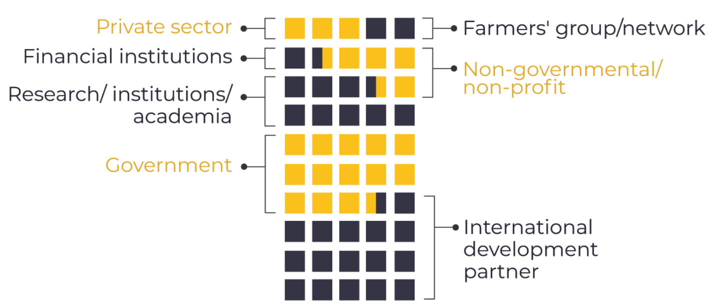
30% Economic

16% Social/cultural

9% Environmental

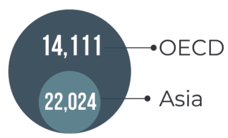
Institutions supporting CSA by type

(based on expert perception of organizations actively supporting CSA)



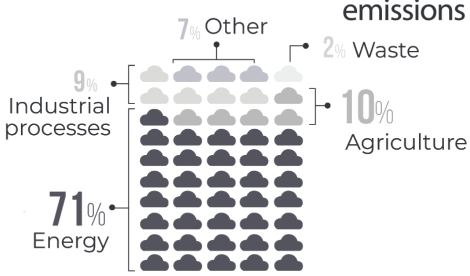
Asia

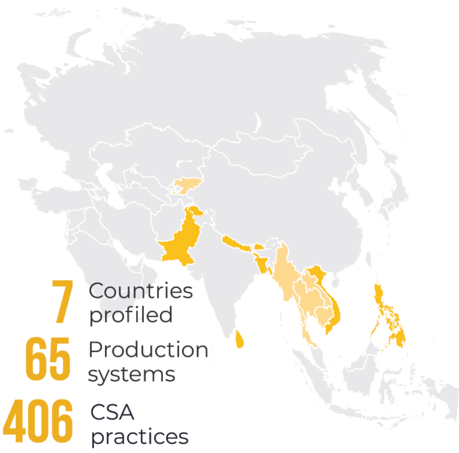
Region at a glance



Total emissions
Mt CO_2 eq

Sectoral emissions





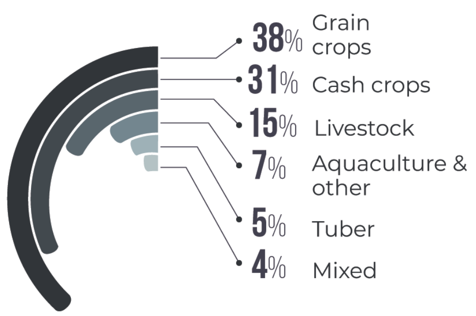
7 Countries profiled
65 Production systems
406 CSA practices

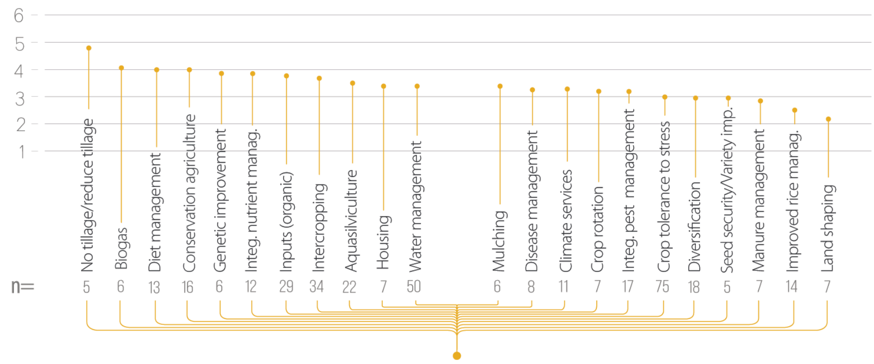
CSA Profile Footprint
Share of regional:

Crop Area **13%**
Cash Crop Area **10%**
Agricultural Emissions **18%**
Cereal Production ($) **20%**
Livestock Production ($) **19%**

CSA trends

CSA frequency by commodity type

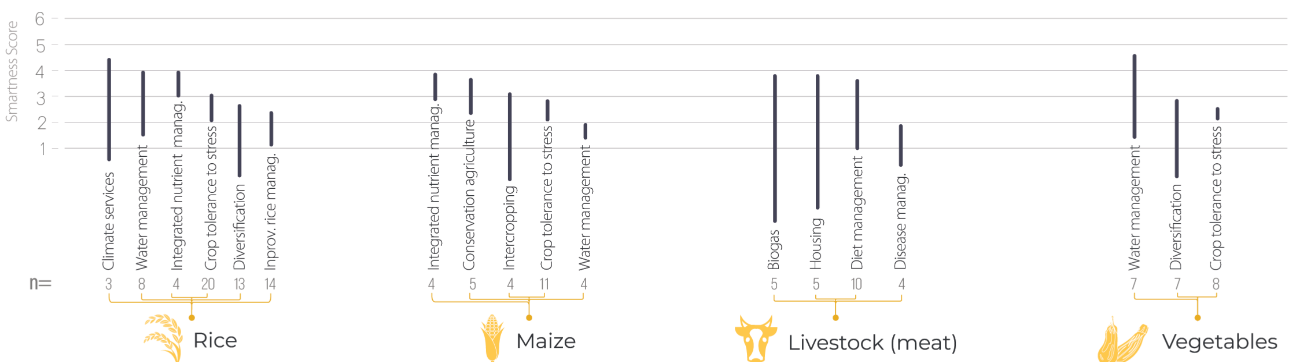




CSA smartness and frequency by technology cluster (all crops, all countries)

CSA in major production systems

(top-scoring technologies in commonly prioritized production systems)



Barriers and Institutions

Barriers to CSA adoption

(percentage of technologies affected by barrier according to experts)

90% Training/ information

30% Policy/ institutional

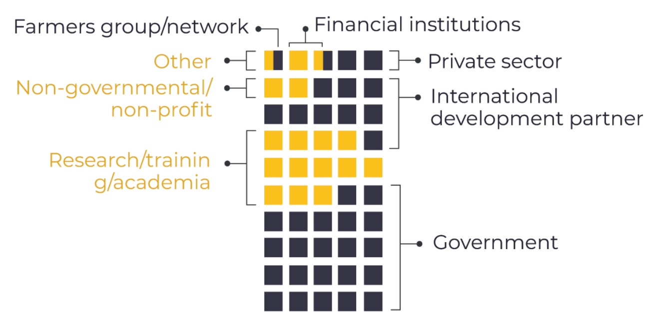
27% Economic

38% Social/cultural

10% Environmental

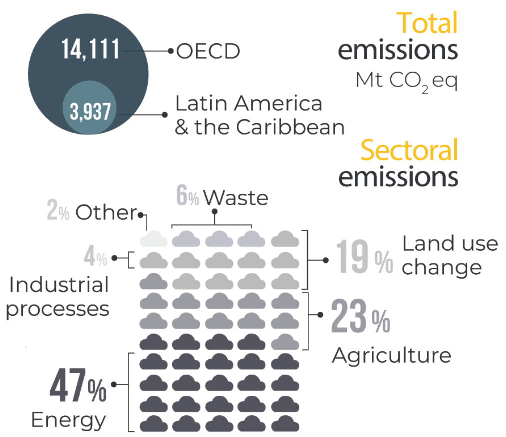
Institutions supporting CSA by type

(based on expert perception of organizations actively supporting CSA)



Latin America & the Caribbean

Region at a glance



10 Countries profiled

68 Production systems

304 CSA practices

CSA Profile Footprint
Share of regional:

Crop Area 40%

Cash Crop Area 34%

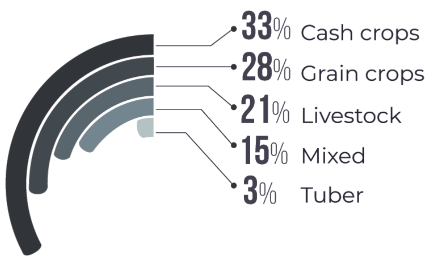
Agricultural Emissions 34%

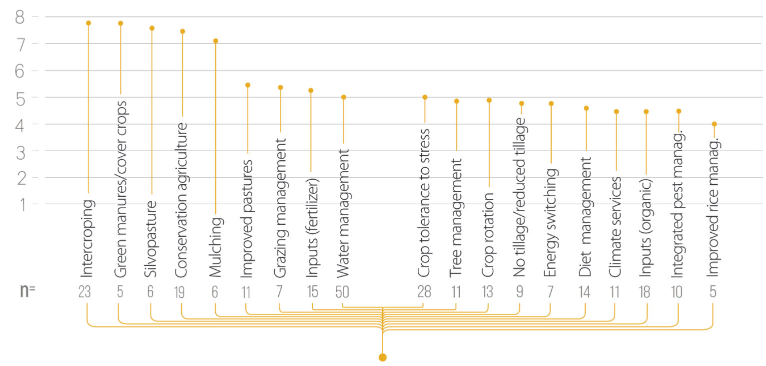
Cereal Production ($) 33%

Livestock Production ($) 28%

CSA trends

CSA frequency by commodity type

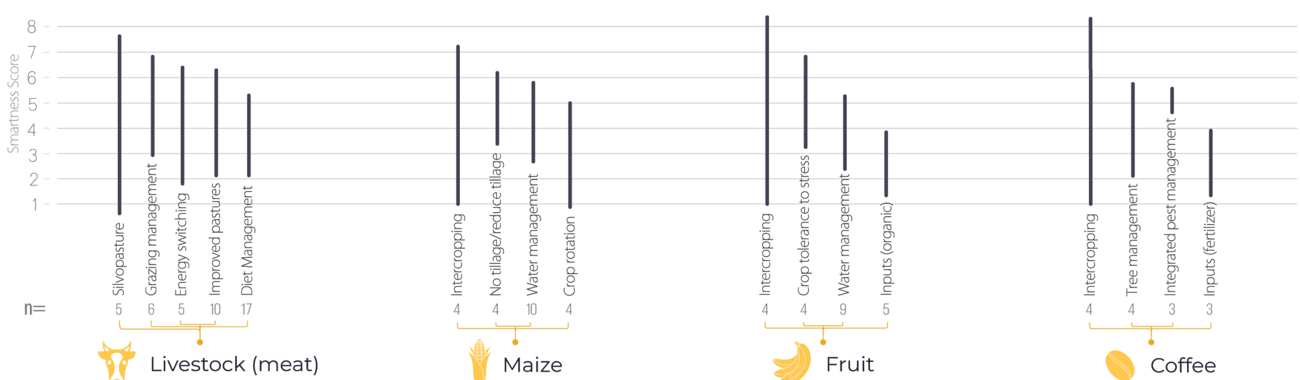




CSA smartness and frequency by technology cluster (all crops, all countries)

CSA in major production systems

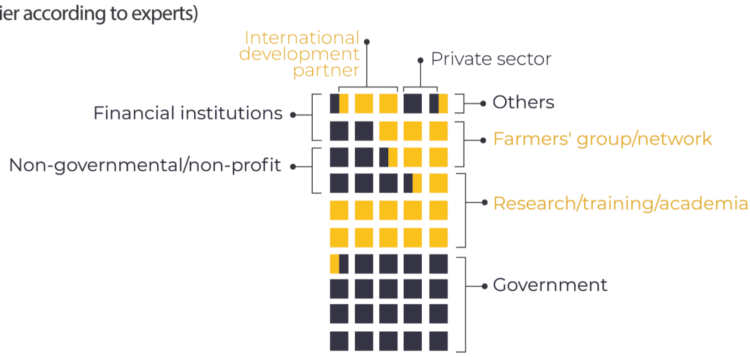
(top-scoring technologies in commonly prioritized production systems)



Barriers and Institutions

Institutions supporting CSA by type

(percentage of technologies affected by barrier according to experts)

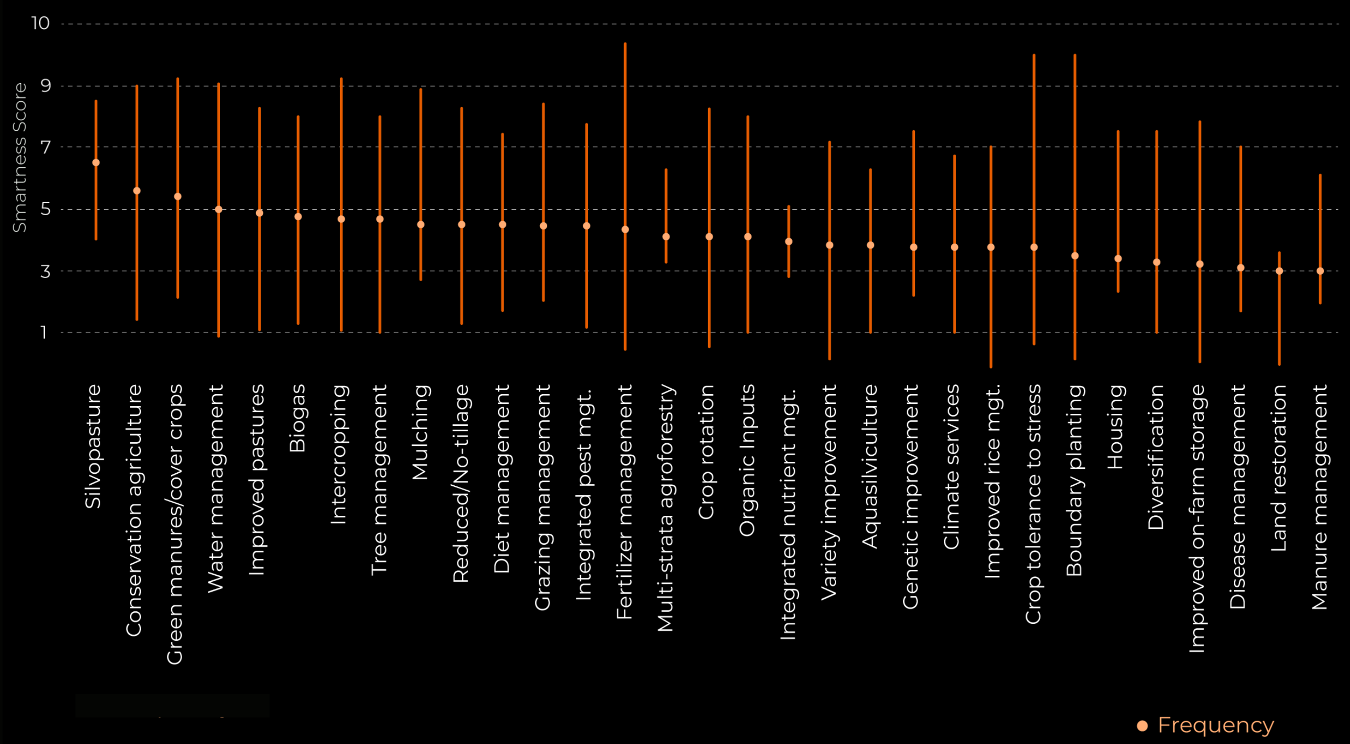


Insight 4

Climate-smartness is a function of context, not an innate property. The smartness of a given CSA technology can vary considerably between different production systems and locations.

Climate-smartness is highly context-dependent (figure 7). The average difference between minimum and maximum smartness scores for all technologies considered climate-smart globally is 6.34 points[1] (on a -10 to +10 point scale). For example, the smartness score for improved fertilizer management varies by up to nine points between contexts, the largest single variation of any CSA technology. Similarly, roughly two-thirds of the smartness scores for boundary planting—identified 19 times globally by local experts—fall between 0.89 and 6.19, a considerable range (the largest standard deviation of any technology cluster). In Rwanda, stakeholders scored the technology 9.04 with strong marks for water and nitrogen smartness when applied in maize systems. A similar boundary planting intervention, however, scored just 0.06 in Senegal among vegetable farmers, with only positive carbon smartness identified by experts. For other technologies such as integrated nutrient management (min-max difference of ~2.3 points) and multi-strata agroforestry (~3.0), scores are less dispersed.

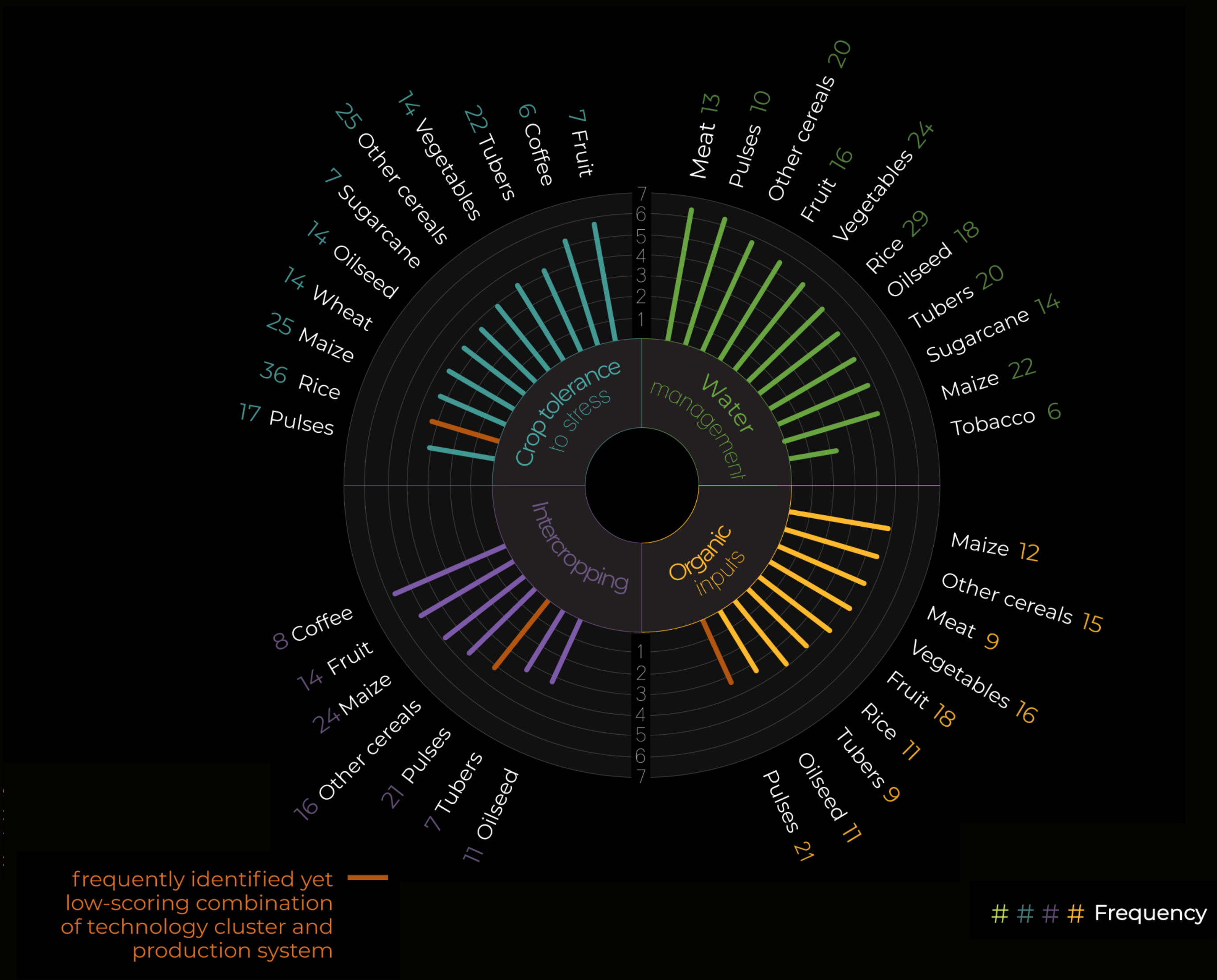
Figure 7. Minimum, Maximum, and Average Smartness Scores of Technology Clusters Considered Climate-Smart (global) (n>10)



[1] Note that for the 10 Latin American countries, climate-smartness was measured on an entirely positive scale (0-10). When normalized across scales, this min-max distance will be greater still.

The climate-smartness of a given technology cluster can also vary considerably across production systems. Figure 8 shows the smartness scores of technology clusters most frequently considered climate-smart globally (water management, crop tolerance to stress, intercropping, and use of organic inputs) across different agricultural production systems. Some of the clusters most commonly selected by experts for a given cropping system yield the lowest average perceived smartness scores. For example, the organic inputs technology cluster was most often applied to pulse crops where it achieved its lowest average smartness score from experts. This result is also true of crop tolerance to stress when applied to rice systems, and intercropping when applied to pulses. Ultimately, climate-smart agriculture is an approach, not an assessed list of interventions. The results of this global synthesis support the CSA community's reluctance to overdefine or produce a static list of climate-smart technologies across contexts.

Figure 8. Smartness Scores for Technology Clusters Frequently Identified as Climate-Smart Across Production Systems (global) (n>5)



Insight 5

CSA technologies with the highest smartness scores are not always widely prioritized by experts and widely identified technologies do not always hold the highest smartness scores.

CSA technologies with the highest perceived smartness scores are not always widely identified by experts as climate-smart. For example, silvopasture is the highest ranked CSA technology in Africa, with an average score of 5.78. Yet stakeholders identified this technology on just six occasions across 17 countries (representing 0.6 percent of all technologies). Similarly, silvopasture holds an average CSA smartness score of 7.62 in LAC, but was also identified just six times (2 percent of all technologies). To a large extent, the frequency that a technology is identified as climate-smart in this global dataset is a function of applicability and is not a universal recognition of that technology's climate-smartness. In other words, the smartness of a technology depends on the system under analysis. Yet even within the same production system—maize, for example—boundary planting was identified as climate-smart on just three occasions (representing just 1.6 percent of all technologies), despite an average smartness score of 7.10. Crop tolerance to stress represents 14 percent of all maize technologies (n=25) but scored, on average, just 3.31. While always subject to local contexts, the relationship between frequency and smartness provides useful insights into key technology groupings (table 1).

Table 1. Emerging CSA Technology Clusters: frequency and smartness

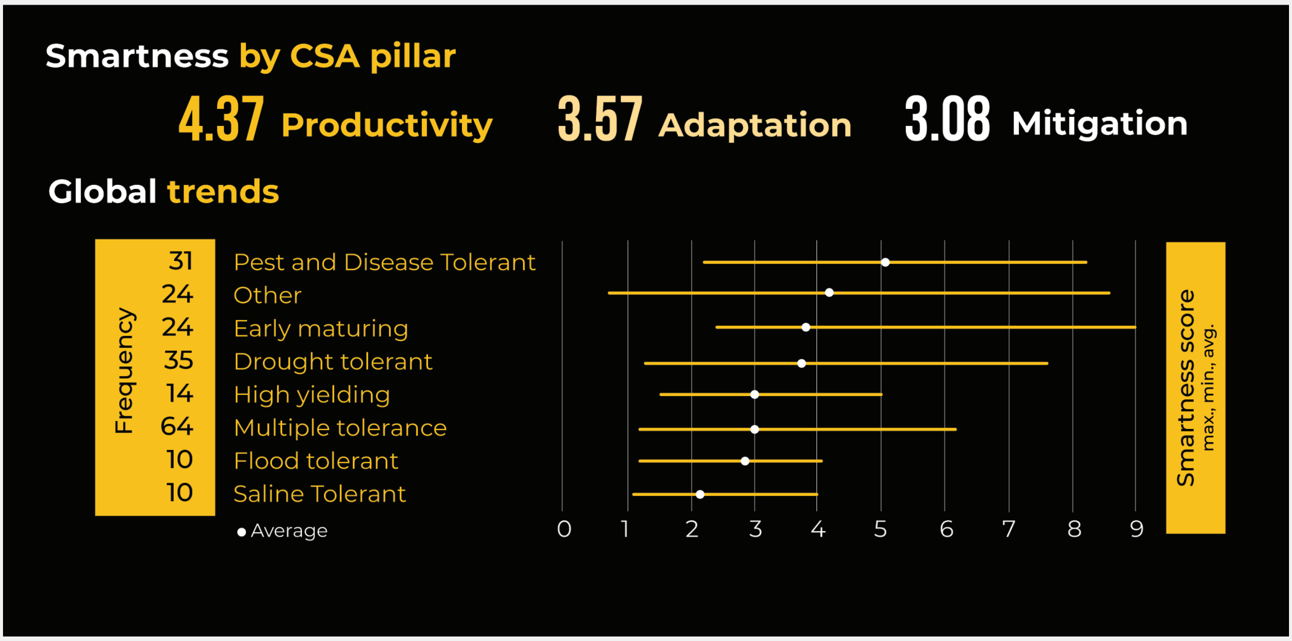
High Frequency, High Smartness	Water Management (n=230; s=4.95) Intercropping (n=160; s=4.74) Organic Inputs (n=150; s=4.13)	The highest performing CSA technology clusters globally. These suites of interventions are both frequently identified by local experts as climate-smart and hold higher-than-median climate-smartness scores. These are high-scoring, well-known clusters.
Medium Frequency, High Smartness	Conservation Agriculture (n=83; s=5.57). Crop Rotation (n=80; s=4.14) Fertilizer Management (n=71; s=4.34)	Clusters that perform above the global average for smartness and are selected at a moderate rate (n>50). Collectively, these constitute technologies that show high potential but could benefit from continued scaling and awareness-building.
Low Frequency, High Smartness	Green Manure (n=18; s=5.43) Silvopasture (n=13; s=6.49) Energy Switching (n=9; s=5.59)	Clusters with high smartness scores—especially in the mitigation pillar—but identified as climate-smart only a small number of times. These are high-potential strategies that would benefit from continued scaling and promotion or increased research into potential adoption barriers. These clusters have high mitigation potential that could benefit society more broadly. Farmers may require additional incentive mechanisms to adopt them.
High Frequency, Low Smartness	Crop tolerance to stress (n=214; s=3.66)	This cluster is an outlier, frequently selected but with a lower-than-average global smartness score. This outcome may be the result of the composition of the expert groups consulted in Country Profile development, privileging expertise in crop and cereal systems and improved crop varieties.

Note: n=frequency, s=average smartness score.

Crop Tolerance to Stress: A Deeper Dive

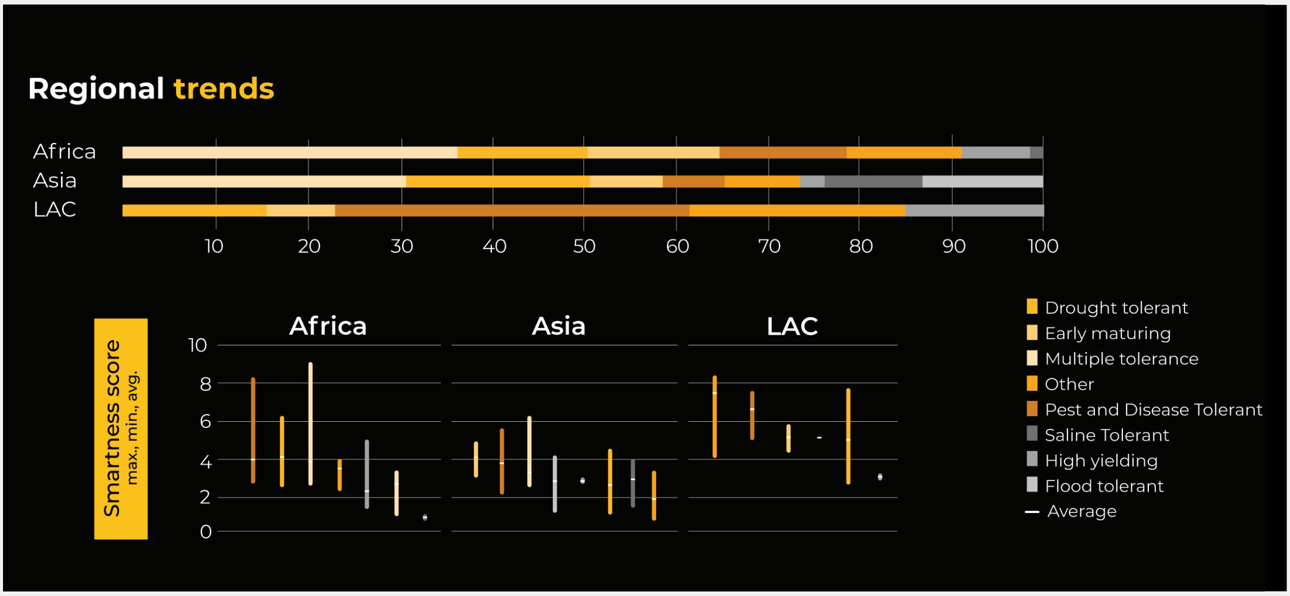
Each technology cluster shown in this global analysis is composed of a host of higher-resolution CSA technologies. Crop tolerance to stress is among the most commonly identified CSA technology clusters globally. This group accounts for almost 13 percent (n=214) of all technologies considered climate-smart by experts across the three regions, despite its lower-than-average smartness score. It includes the use of crop varieties with improved tolerance to variations in temperature and moisture conditions as well as the use of certified seeds.

Global: Following multiple stress-tolerance combinations (for example, drought tolerant and early maturing; saline tolerant and high yielding), drought tolerance was the most commonly identified sub-category, accounting for 16 percent of all selections. This sub-category was followed by pest and disease tolerance and early maturing varieties. As with CSA technologies more broadly, the most commonly selected tolerance sub-categories are not necessarily the highest scoring. Tolerance to multiple stressors (3.05) was frequently identified as climate-smart. However, its score was below the global average smartness score (3.66) for all crop tolerance to stress sub-categories. The "other" category, which includes the use of certified seeds and heat- and cold-tolerant crop varieties, was selected just 11 percent of the time, but scored 4.29—well above the global smartness average for crop tolerance to stress. In general, less research has been undertaken to develop heat-tolerant varieties in comparison to the tolerance of other stressors like drought.



While crop tolerance to stress technologies score close to the global mean in regard to productivity (4.37), this cluster's average smartness for both adaptation (3.57) and mitigation (3.08) pillars falls well below global mean. The adoption of improved crop varieties, despite their potential to adapt to new and changing climatic conditions, may be driven predominantly by considerations relating to productivity rather than adaptation or mitigation, or may simply reflect experts' preference for productivity outcomes, a bias evident across most technologies in this synthesis.

Regional: These global results hold several regional variations. While "multiple" and drought tolerance are the largest single crop tolerance sub-categories globally, pest and disease tolerance are the most common tolerance or resistance trait selected by experts in LAC. Saline- and flood-tolerant varieties, meanwhile, are almost entirely unique to Asia while high yielding varieties were not widely selected in that same region.



In LAC, "other varieties", which includes certified and heat-tolerant seeds, was the highest scoring crop tolerance to stress sub-category (7.67). In Asia, early maturing varieties was the highest scoring (4.12). Pest and disease tolerance is considered a highly climate-smart sub-category across all regions. In comparing stress-tolerant varieties of grain crops and cash crops, grain crops seem to be more climate-smart, especially in LAC and Asia.

Insight 6

CSA appears to coincide with common-sense agriculture. Income and profit indicators were rated almost uniformly positive for all CSA technologies by experts.

Any intervention identified by experts that contributed to at least two of the three pillars of CSA—productivity, adaptation, and mitigation—was considered for inclusion in CSA Country Profiles. Across all regions and technologies, experts scored productivity measures (composed of yield, income, and profit indicators) the highest (an average of 4.48, compared to 4.3 and 3.9 for adaptation and mitigation pillars, respectively) (see table 2). Almost all technologies considered climate-smart for each region showed positive income or profit smartness (see trade-offs discussion in next section).

This potentially reflects the relative ease of identifying yield and income impacts for these strategies; experts have long been trained to pursue yield and on-farm income improvements over other considerations. It may also reflect the prioritization of these benefits over adaptation or mitigation. Productivity biases, however, are not universally present. Some low frequency, high smartness technologies such as green manure, energy switching, and silvopasture did receive high mitigation pillar scores by experts, reflecting the importance of climate mitigation in the choice of CSA practices. Still,

the data presented here demonstrate that measures of yield and income are important in encouraging adoption of CSA technologies. Higher productivity remains a binding constraint in identifying climate-smart technologies, while adaptation and mitigation are more likely considered as co-benefits.

Table 2. Mean and Median Smartness Scores (all technologies) (global)

	Productivity Smartness (P)	Adaptation Smartness (A)	Mitigation Smartness (M)	Total Smartness (T)
Median Score[a]	4.0	4.94	3.70	3.94
Mean Score	4.48	4.30	3.91	4.31

[a] The median climate-smartness score varies considerably between regions (Asia 3.34, Africa 3.64, Latin America 6.64). This result is due, in part, to methodological changes during the course of the CSA Country Profile development process, especially in LAC where smartness scores were produced on an entirely positive scale (0-10).

Case in Point—Productivity Driving CSA Uptake

Improving farmer income is central to CSA adoption and sustainability. In Lower Nyando, Kenya, communities are participating in Climate-Smart Villages designed to test and deploy CSA strategies. The increased adoption of agroforestry and alley cropping has helped to spur investments in 22 private tree nurseries in the surrounding area, half of which are women-owned. These investments will help to sustain momentum around agroforestry practices while simultaneously strengthening the rural economy, and provide alternative livelihood opportunities for entrepreneurs in Lower Nyando.

Insight 7

While trade-offs exist, most CSA technologies demonstrate synergies between the productivity, adaptation, and mitigation pillars. There are ample opportunities for co-benefits and triple-wins.

The identification of trade-offs and synergies between the productivity, adaptation, and mitigation pillars is among the core contributions of CSA Country Profiles. Experts across the three regions overwhelmingly identified technologies as climate-smart with considerable synergies between CSA pillars, rather than profound trade-offs. Figure 9 shows the relative weight of each pillar in contributing to a technology's total smartness score. Almost 90 percent of technology clusters (40 of 44) have perceived benefits that span all

three CSA pillars. Biological control of vectors, heat management, improved cookstoves, and risk insurance are the four exceptions. Even these clusters, however, show co-benefits with another CSA pillar. Technology clusters with especially high synergies (and high frequency) include conservation agriculture, crop rotation, use of organic inputs, mulching, diversification, and reduced/no-tillage. With the exception of diversification, each of these highly synergistic technology clusters hold smartness scores above the global average.

Still, trade-offs are apparent in the data. CSA Country Profile experts assessed climate-smart technologies on a scale from -10 to +10, with negative values representing undesirable impacts on an indicator. Negative values signal potential trade-offs for technologies considered climate-smart[2]. In Africa and Asia, the CSA indicator with the largest number of negative values is soil health (adaptation pillar), followed by energy (mitigation) and nitrogen indicators (mitigation). Experts were least likely to identify trade-offs (that is, undesirable effects or negative values) for productivity, especially income, and more likely to allow trade-offs for adaptation and mitigation pillars, especially soil health, energy, and nitrogen indicators. Technologies with trade-offs in this global synthesis have slightly lower than average productivity benefits while adaptation and mitigation scores are far below the mean (table 3). In other words, experts believe that farmers may tolerate reduced soil health or reduced nutrient-use efficiency for gains in other indicators, but they will not tolerate income losses.

Table 3. Average Smartness of Technologies with Trade-Offs (with at least one negative indicator)

	Productivity	Adaptation	Mitigation
Technologies with trade-offs	4.15	1.94	2.02
All technologies	4.48	4.30	3.91

The highly synergistic nature of many technologies is clearly visible when each CSA pillar is mapped separately (figure 10). Five technology clusters—tree management, improved pastures, silvopasture, conservation agriculture, and water management—are included in the top 10 technologies for smartness for the mitigation, adaptation, and productivity pillars. Among the smartest technologies globally, interventions considered highly climate-smart in one pillar are often considered highly climate-smart in the others. The notable exception is biogas which scores high in both mitigation and adaptation smartness but low in productivity.

[2] Numerous trade-off models have been developed and there are additional methods to assess the more intimate conflicts between indicators for each practice (beyond the use of negative values applied here). We did not attempt a high-resolution comparison here, but a full tradeoff assessment of any CSA priority would be needed prior to investment. Additionally, there are other transaction costs not captured here that may affect technology adoption—high productivity assessments do not translate automatically into high rates of technology adoption.

Figure 9. Productivity, Adaptation, and Mitigation Contributions to Overall Smartness Scores of Technologies Considered Climate-Smart (global)

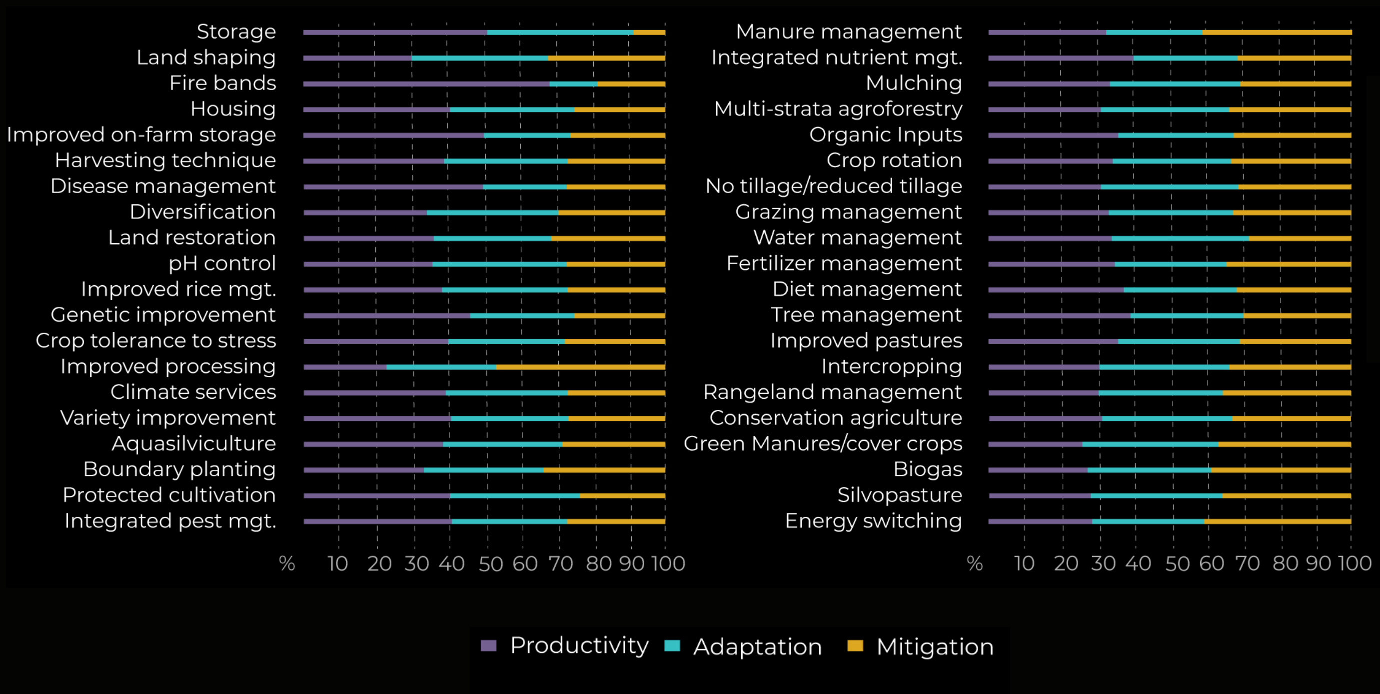
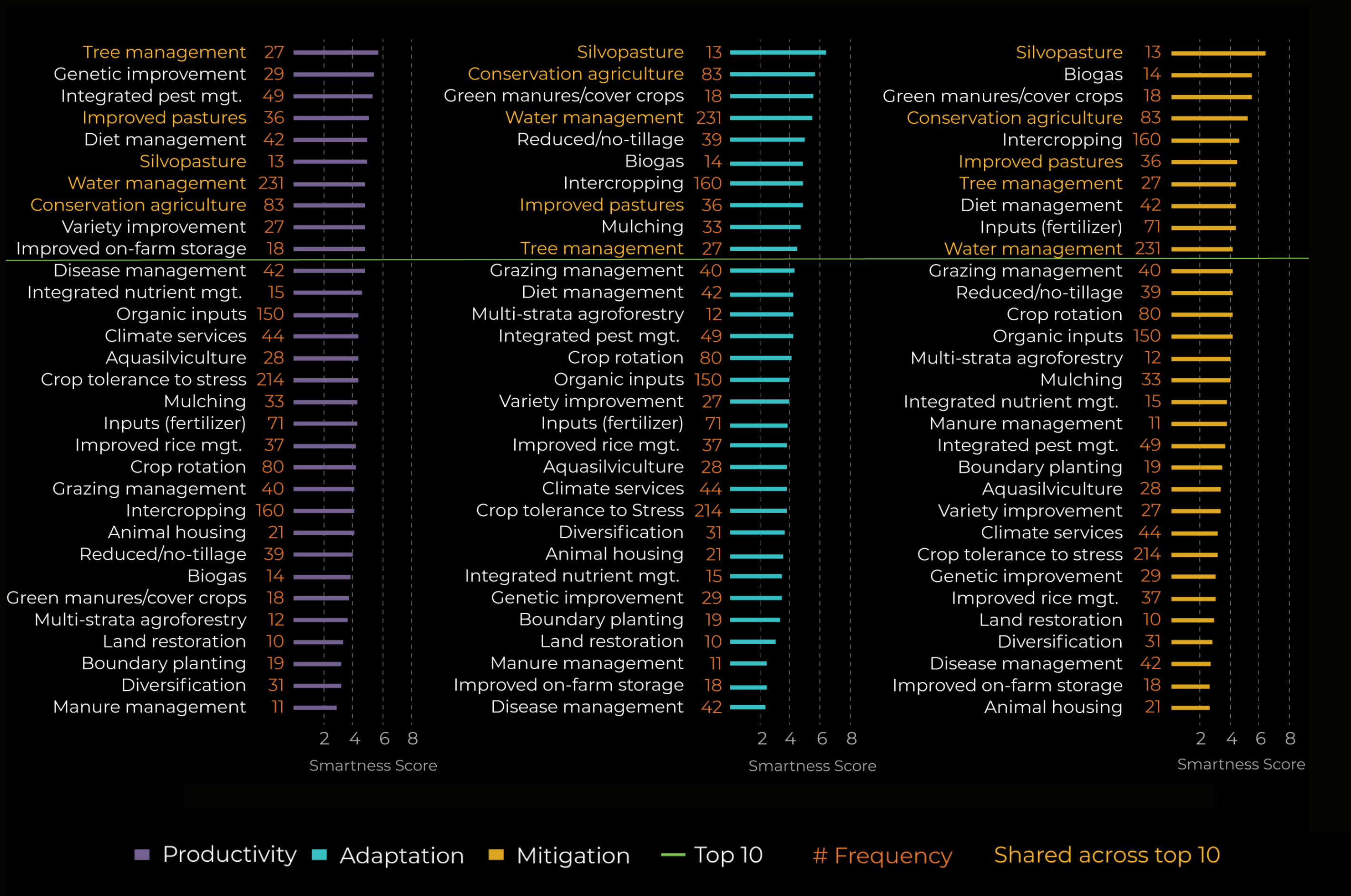


Figure 10. Smartness Scores of Climate-Smart Technologies by Pillar (global)



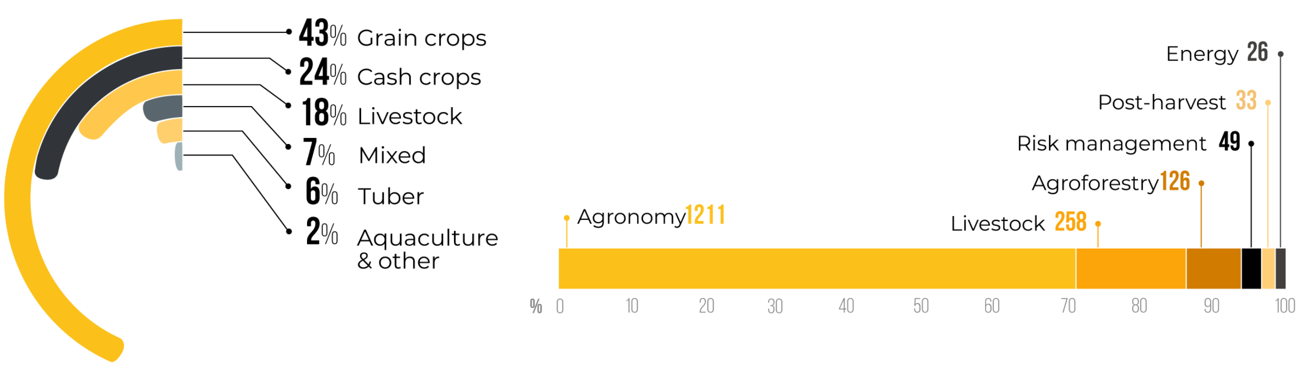
Insight 8

Technologies considered climate-smart in CSA Country Profiles focus disproportionately on cropping systems, especially cereal crops.

Across all regions, CSA technologies were most commonly identified by experts for food crops such as rice, maize, and wheat. In fact, 43 percent of all technologies analyzed globally relate to these and other food crops (figure 11). Another 24 percent of technologies considered climate-smart pertain to cash crops like coffee, cocoa, and rubber.[3] However, only 20 percent of all interventions relate to either livestock or aquaculture, despite the fact that livestock production alone represents almost 35 percent of all agricultural production (US$) in the countries included in this analysis (FAOSTAT 2016). Cereal crops like maize, wheat, and rice are important food security crops and are widely grown. This bias, then, stems from a deliberate prioritizing of food security considerations in the profile methodology. It is also, in part, the product of experts consulted for Country Profiles specializing disproportionately on crop and cereal systems. Yet demand for animal protein is growing at a rapid pace as more people enter the global middle class. CSA advocates and practitioners must work to close the knowledge gap with regard to key climate change adaptation and coping strategies for livestock and aquaculture production systems.

The focus on food crops is not universal across regions. In LAC, for example, the largest single commodity-type grouping is cash crops. While in Asia, commodity-type trends are more balanced across food crops, cash crops, livestock, and fisheries.

Figure 11. Technologies Considered Climate-Smart by Commodity Type and CSA Category (global)



[3] Cash crops include perennial crops (coffee, cocoa, rubber, cashew nuts), sugar, vegetables, and fruits.

Case in Point—Value Chain Climate Risk Profiles

Acknowledging the on-farm technology bias present in CSA Country Profiles, the International Centre for Tropical Agriculture (CIAT); Kenya Ministry of Agriculture, Livestock and Fisheries; and the World Bank have developed 31 Climate Risk Profiles at the subnational (county) level in Kenya. Risk Profiles examine key commodities, map vulnerabilities and risks across the value chain from input provision to marketing, and identify adaptation strategies and off-farm services for combating these risks. Climate Risk Profiles are being developed in the Philippines for the three Island groups (Luzon, Visayas, and Mindanao). CIAT is preparing these profiles for the Philippine Department of Agriculture and FAO, and they will be used with others to prepare a proposal to the Green Climate Fund.

Case in Point—Climate Risk Management

While risk management technologies do not feature centrally in this analysis, efforts to provide smallholder farmers with improved climate information services are being widely undertaken globally. In Benin, for example, researchers, farmers, and local decision makers have come together in farmer field schools to discuss and disseminate climate information prior to and during the planting season. With the help of key partners in the Ministry of Agriculture (MAEP), the National Agricultural Research System (INRAB), national universities, and the National Meteorological Service (Meteo Benin), more than 300 farmers in 60 field schools interact with meteorologists and climate researchers to make informed choices about when to sow and harvest crops. These same schools serve as platforms to disseminate innovative agricultural practices and improved crop varieties.

An extension of this cereal crop bias is that almost 70 percent of all technologies considered climate-smart fall into the broad CSA category of agronomy (that is, soil management and crop production). Technologies related to energy, risk management, and post-harvest categories were not widely identified in any region. In fact, energy technologies such as biogas, improved cookstoves, and alternative on-farm energy sources represent just over 1.5 percent of all technologies identified globally as climate-smart. Among the small number of mentions, these energy technologies are most common in LAC.

The primary focus of CSA Country Profiles is on-farm technologies, leaving considerable space for the continued investigation of downstream or enabling environment-type services. For example, technologies related to post-harvest processing and risk management (n=82) (for instance, climate services, risk insurance, and so on) account for less than five percent of all technologies considered by experts to be climate-smart. Off-farm, downstream or enabling environment technologies represent just 3 percent of interventions prioritized by experts globally.

Case in Point—Strengthening Livestock in CSA

Stakeholders–public as well as private-aiming to develop climate-smart livestock investments often lack adequate information and tools to support them. The "Guide to Investing in Sustainable Livestock: Environment," a joint web resource being developed by the World Bank and the FAO, aims to close this gap. The tool simplifies sustainability in livestock production and processing by identifying seven core principles, the application of which is explained through practical guidance for six specific contexts, covering different climatic conditions and livestock farming systems. The tool will be completed in early 2019 and launched through a joint World Bank-FAO event.

Guide to Investing in Sustainable Livestock: Six Contexts

Livestock species	Farm size	Climate	Livestock system
Ruminants	Small	Dry to temperate	Mixed crop/livestock
Ruminants	Small to Medium	Dry	Pastoral (mobile grazing)
Ruminants	Small to Medium	Semi-dry to humid	Grazing
Ruminants	Medium to Large	Temperate/cold	Grazing
Monogastrics	Medium	Various	Intermediate and Industrial
Monogastrics	Small to Large	Humid tropics	Mixed crop/livestock

Insight 9

Training and information were identified as the single largest barrier category to CSA adoption across all regions, affecting almost 90 percent of all interventions.

Cost-benefit analysis is often used to predict technology adoption. But contrary to this conventional wisdom, the most commonly identified barriers to CSA technology adoption in this global synthesis were not economic in nature. Instead, training and information barriers were identified by CSA Country Profile experts as the single largest barrier category across all regions, affecting almost 90 percent of all interventions (figure 12). The prominence of training and information barriers points to the critical importance of research and academia in this quickly evolving area. Many CSA technologies are knowledge-intensive.

Case in Point—Overcoming Information Barriers

Increasing the adoption rate of potential CSA strategies such as biogas requires improved information dissemination, and engagement with the private sector. In Tanzania, construction of biogas digesters to produce fuel for household and farm needs was undertaken with funding from the Netherlands Development Organization. This effort was supported by Sokoine University to encourage practice dissemination. Key to the project moving forward is the private sector's engagement in the design, manufacture, and repair of biodigesters. This CSA technology spans sectors, from agriculture to health, and sanitation to energy, making it a priority intervention for the country's poverty alleviation goals and its efforts to support small and medium enterprises.

Of particular importance will be to further develop and test location, and system-specific knowledge on CSA technologies as well as delivery mechanisms and required policy and enabling environments. Training and information barriers were followed by policy and institutional barriers (affecting 36 percent of interventions), economic barriers (31 percent), socio-cultural barriers (25 percent), and environmental barriers (9 percent).

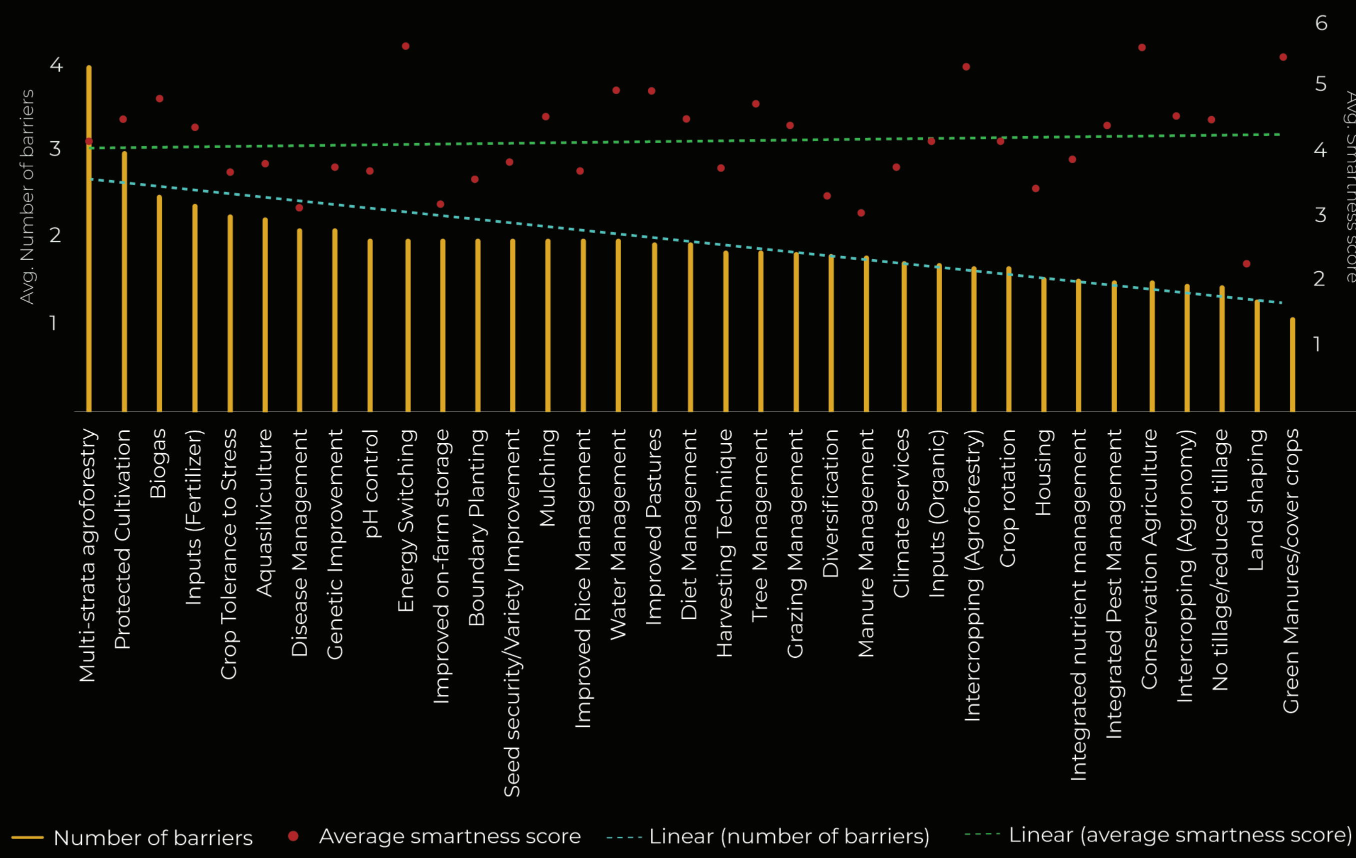
While these trends were similar between regions, socio-cultural barriers were found to be stronger in Asia. Policy and institutional barriers were more frequently identified in African countries, characterized by poorly functioning agricultural extension systems, limited access to input and output markets, inefficient risk management systems, and scarce social safety net systems.

Figure 12. Barriers to CSA Technology Adoption (global)

Note: Percentage of technologies affected by barrier according to experts.

High, smartness technologies do not appear to be disproportionately plagued by a higher number of barriers to implementation (figure 13). Instead, and perhaps intuitively, technologies with an especially high number of barriers tend to be those requiring the involvement of multiple actors in the implementation process, and those that are knowledge- and capital-intensive such as multi-strata agroforestry, biogas, genetic improvement, disease management, and crop tolerance to stress (which often requires research, seed multiplication, and distribution). Conversely, technologies that can be implemented more easily by the farmers themselves tend to be perceived as having a lower number of barriers (for example, crop rotation, conservation agriculture, intercropping, reduced/no-tillage). Many of these technologies have above-average smartness scores.

⦿ **Figure 13. Climate-Smartness with Barriers to Adoption (global)**



While more research is required to determine the specific magnitude of these barriers, there is an early indication that specific barriers have a disproportionately strong impact and can produce a bias in the scoring of certain interventions identified as climate-smart.

For example, the identification of training/information and social/cultural barriers reduced climate-smartness scores between 5 and 10 percent across all practices, speaking to the potential weight of these barriers. (figure 14).

⦿ **Figure 14. Smartness Scores of Technologies Considered Climate-Smart, with and without Select Barriers (global)**

Note: Percentage of technologies affected by barrier according to experts.

Barriers to CSA adoption are influenced by the composition of institutions and organizations supporting farmers in implementing and scaling CSA technologies. Organizations play distinct roles in promoting and implementing CSA, such as: developing enabling policies, undertaking research, providing funding, and sharing knowledge and expertise, among others. Globally, the single largest CSA-related institutional category is government, which often includes ministries of agriculture, environment, finance, and planning (figure 15). Government actors represent the largest institutional grouping in both Asia and Latin America. In Africa, however, international development partners represent over one-third of all institutional actors. These partners include multilateral and bilateral development agencies (serving as the largest single source of funding for CSA implementation), international non-governmental organizations, networks, and alliances. Research, training, and academic institutions will play a central role in the success of CSA scaling. These organizations represent between 15 and 25 percent of CSA-related institutions, depending on the region. Private sector organizations represent just five percent of CSA-related institutions globally.

Figure 15. Involvement of CSA-Related Institutions (global)

Insight 10

There is no CSA "silver bullet" and the smartness of a system depends on more than the technologies deployed at plot level.

CSA Country Profiles include a wide array of stakeholders, and take into account complex socio-economic, environmental, and political landscapes around climate-smart agriculture. These profiles have been critically important tools for building technical and political momentum and have fostered a strong group of CSA advocates poised to continue development and implementation of practices in each country.

Case in Point—Climate Smart Investment Plans

The Climate Smart Investment Plan (CSIP) approach developed by the World Bank in collaboration with CIAT, the International Institute for Applied Systems Analysis, CEA, and others builds on the highly successful CSA Profile Series. Where CSA Profiles provided a stocktaking and overview, CSIPs use this information, applying participatory analytical tools to identify sets of transformative CSA investment and policy opportunities in support of countries' climate commitments. The analytical tools are tailored to each country context but include visioning exercises, robust decision making under uncertainty, and quantitative modeling—and are all deployed collaboratively with the client team and multiple in-depth stakeholder consultations. As a result, clients are able to identify investment and policy opportunities in the agriculture sector that increase productivity and incomes, strengthen the sector's resilience to climate-change impacts, and reduce emissions. The proposed opportunities will be contextualized within existing client policies and targets and be presented in different formats depending on context.

CSIP pilots are under way in Bangladesh and Zambia, and CSIPs are being developed using similar methodologies tailored to local conditions in Côte d'Ivoire, Lesotho, Mali, and Zimbabwe. Pilots have shown encouraging results, providing a practical avenue toward integration and implementation of Nationally Determined Contributions and agriculture sector strategies. The combination of participatory processes with quantitative elements to inform prioritization of investments has proven effective. This strategy has resulted in a shortlist of interventions with specified parameters across the "what and how" of technical content, implementation, and financing mechanisms, as well as accompanying policy interventions. Each CSIP identifies financing needs for the prioritized CSA opportunities and discusses potential sources to cover these needs, including by following the Maximizing Finance for Development (MFD) approach to leverage private sector finance and exploring opportunities to attract climate finance.

Lessons learned and critical success factors identified during the pilot phase include the following:

- Client ownership is imperative; CSIPs should be programmed well in advance to allow sufficient time to engage with clients to build ownership.

- Local knowledge is key to understanding the specific context and interlinkages between climate change and agriculture.
- Reverse-engineering approaches are useful to define the CSIP methodology.
- Selectivity of interventions, while challenging, is necessary as it sharpens the focus of analysis and increases stakeholder engagement.
- Building local capacity in modeling is necessary to ensure clients can use the tools after CSIP development is completed.

Going forward, the Country Profile methodology will further evolve including to better reflect system level aspects (including the landscape level) and to integrate newly available evidence on impacts from CSA projects, pooling all scientific evidence into one large dataset, the CSA Compendium. Integrated landscape level approaches are best suited to manage synergies and tradeoffs across different land use intensities and agriculture production systems, facilitating multidimensional decision making. Beyond continued outreach and expansion of the Country Profiles' global footprint (both in terms of countries and continents), the next chapter in CSA's story will be embedding Country Profiles into a broader suite of decision-making tools—from Climate Smart Investment Profiles to subnational Climate Risk Profiles—that take into account competing sectoral priorities, the cumulative effect of combined suites of CSA technologies, and the potential for transformational change in global food systems. The next step is to move beyond the "practice" lens of CSA alone. The smartness of a system depends on more than the technologies deployed at plot level. Even the best technologies would not make an agricultural system climate-smart where slash and burn agriculture, extensive soil erosion and the expansion of degraded lands prevail, for example. By using CSA Country Profiles, CSIPs, and subnational Climate Risk Profiles, countries can better prepare their food systems for the impacts of climate change in an integrated way that reduces the sector's contribution to the underlying problem, thus addressing one of the most pressing challenges of our time.

"Concise as it is, [the CSA Country Profile] is a helpful reference for policy makers, technical people and agri-fishery practitioners in crafting policies, programs and projects for the sector. DA-SWCCO used the relevant information in the CSA Country Profile in presenting the Adaptation and Mitigation Initiative in Agriculture (AMIA) program, serving as the backgrounder and recommending ways forward."

—**U-Nichols Manalo,** Director, Systems-Wide Climate Change Office, Philippines Department of Agriculture

Annex 1. CSA global data set categories

In the combined global dataset used in this report, in addition to the recorded continent, country, region, agro-ecological zone, adoption rates, climate-smartness scores, and adoption barriers produced during the Country Profile development process, each CSA practice was assigned metadata related to commodity, commodity-type, CSA category, and CSA technology cluster. CSA categories—agronomy, livestock, agroforestry, risk management, energy, post-harvest or organization—were derived from categories previously defined in the CSA Compendium. Metadata categories are as follows:

CSA category

- Agroforestry
- Agronomy
- Energy
- Livestock
- Post harvest
- Risk management

CSA Technology Cluster

- Aquasilviculture
- Biogas
- Biological control of vectors
- Boundary planting
- Climate services
- Conservation agriculture
- Crop rotation
- Crop tolerance to stress
- Diet management
- Disease management
- Diversification
- Energy switching
- Fire bands
- Genetic improvement
- Grazing management
- Green manures/Cover crops
- Harvesting technique
- Heat management
- Animal housing
- Improved cookstoves
- Improved on-farm storage
- Improved pastures
- Improved processing
- Improved rice management
- Fertilizer management
- Organic inputs
- Integrated nutrient management
- Integrated pest management
- Intercropping
- Land restoration
- Land shaping
- Manure management
- Mulching
- Multi-strata agroforestry
- Reduced/No-tillage
- pH control
- Protected cultivation
- Rangeland management
- Risk insurance
- Seed security/Variety Improvement
- Silvopasture
- Improved Storage
- Tree management
- Water management

Commodity type

- Grain Crops
- Cash Crops
- Livestock
- Mixed
- Tuber
- Aquaculture and Other

Commodity

- Aquaculture
- Cocoa
- Coconut
- Coffee
- Cotton
- Fruit
- Integrated Farming
- Jute
- Maize
- Meat
- Milk
- Nuts
- Oilseed
- Other Cereals
- Pepper
- Pulses
- Rice
- Rubber
- Spices
- Sugarcane
- Tea
- Tobacco
- Tuber
- Vegetables
- Wheat
- Mixed