CSA-Diagnostic (CSA-Dx)

A primer for investigating the 'climate-smartness' of ag technologies

Todd Rosenstock, Christine Lamanna, Peter Matata, Emmanuel Temu, Mary Ng'endo, Nictor Namoi, Christopher Muller & Anthony Kimaro

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Abstract

Climate-Smart Agriculture-Diagnostic (CSA-Dx) is a primer for conducting research on the ‘climate-smartness’ of agricultural technologies—for determining, that is, how technologies affect the productivity, resilience and mitigation potential of farming activities. CSA-Dx provides a step-by-step guide to enable researchers to create farmer-relevant and decision-relevant information. It offers a three-stage, five-step framework for CSA research, integrating existing resources and recent innovations developed by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), participating centres (including ICRAF) and other institutions and programs. Ultimately, CSA-Dx generates robust data for agricultural technologies across outcomes including productivity, resilience and mitigation. These data provide new information on what works where, when and for whom. This information is directly relevant for program and policy implementation. Much of this document focuses on examples from the United Republic of Tanzania, as CSA-Dx was piloted and designed there with assistance from national agricultural research, government and development partners. The approaches presented here, however, are general and can be broadly adapted and applied.

Box 1: What, who and why of CSA-Dx

What is CSA-Dx? CSA-Dx is a simple how-to guide to diagnose (Dx) the 'climate-smartness' of agricultural technologies in the field—to determine, that is, how new management practices or technologies affect the three objectives of CSA: productivity, resilience and mitigation.

Who should use CSA-Dx? CSA-Dx was designed for researchers and development practitioners who want to collect robust data on technology performance across CSA’s three pillars.

Why use CSA-Dx? CSA-Dx highlights key decisions and resources that will help any researcher conduct farmer-centric research on climate-smart agriculture technologies, whether they are conducting trials on a research station or at hundreds of farms.

Because CSA is outcome-oriented and not prescriptive, any technology qualifies as CSA if it (i) addresses climate risks, (ii) has multiple benefits and (iii) is location- and time-specific. These three factors guide the logic behind CSA-Dx.

Keywords

climate-smart agriculture, multi-functional ecosystems, mother and baby trials, participatory action research, digital data collection, indicators, metrics, resilience, mitigation, adaptive capacity, gender

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Acronyms

CCAFS	CGIAR Research Program on Climate Change, Agriculture & Food Security
CSA	Climate-Smart Agriculture
CSA-Dx	Climate-Smart Agriculture Diagnostic
CSA-PAR	Climate-Smart Agriculture Participatory Action Research
CSA-PF	Climate-Smart Agriculture Prioritization Framework
CSA-PG	Climate-Smart Agriculture Practical Guide
CSA-RA	Climate-Smart Agriculture Rapid Rural Appraisal
FAO	Food and Agriculture Organization of the United Nations
ICRAF	World Agroforestry Centre
IPCC	Intergovernmental Panel on Climate Change
P4S	Partnerships for Scaling Climate-Smart Agriculture Project
RHoMIS	Rural Household Multi-Indicator Survey
USDA-FAS	United States Department of Agriculture-Foreign Agricultural Service

Introduction

Billions of USD has been or will soon be invested in climate-smart agriculture (CSA) programmes globally. As the level of investment is growing, CSA is increasingly endorsed by national, regional, continental and global institutions. The aim of CSA is to help smallholder farmers (1) sustainably increase productivity and incomes, (2) adapt to climate variability and change, and (3) mitigate climate change where possible (FAO 2013). Farm- and field-level management technologies are a core component of most planned CSA investments, policies and programs (see [The CSA Papers](#)).

CSA encompasses a wide variety of technologies and practices. Climate-smart actions include new or improved practices such as adopting drought-resistant crop varieties, reducing stocking rates of animals, or changing harvesting and postharvest storage techniques (Lipper et al. 2014). The vast number of farm-level options that might meet CSA objectives, coupled with the large number of possible outcomes that fit under the three pillars of CSA, has led many development practitioners, scientists and governments to ask the question, “What is CSA, and what is not CSA?” (Rosenstock et al. 2015a).

The dominant research literature offers relatively little guidance. Despite 50 years of agricultural research for development, large gaps in our knowledge remain. Such gaps arise largely because of a bias toward a limited number of products and practices. For example, a recent systematic map based on 313 research studies in East and Southern Africa indicated that 78% of the available data were for maize, and 28% were for fertilizers (Rosenstock et al. 2018). Similar results are found at the country level (see Annex I for analysis of Tanzania (Lamanna et al. 2018)). The research bias towards a few products (e.g., maize) and practices (e.g., nutrient management) means that common options suggested for CSA have received comparatively little study. If we want to support evidence-based decision-making, there is a need for new research targeting under-researched options and farming systems, and specifically targeting key opportunities for resilient and low-emissions productivity.

In some ways, CSA requires a new framework for research. Because CSA is oriented toward multiple outcomes and interested in synergies and trade-offs among them, research must collect information on outcomes across the three pillars. Although multi-objective research is not new, analysis of the literature from more than 800 research studies in Africa found that only about 40% of the published studies include data on two pillars and only 1% of studies collected data on all three (Rosenstock and Lamanna, unpublished). Without co-located and well timed research on two to three pillars, it is not possible to analyse synergies and trade-offs among outcomes (such as economic returns and erosion). This makes it difficult to extrapolate about these relationships with much confidence. Furthermore, CSA studies typically aim to be not research for the sake of research but decision-relevant, specifically targeting challenges experienced by farmers. Consequently, CSA research is demand-driven, with the demand arising from levels ranging from local civil society organizations up through global policy discussions.

CSA-Dx is a research framework to evaluate the ‘climate-smartness’ of agricultural technologies in the field. That is, CSA-Dx explains how to evaluate whether new management practices affect performance along the axes of productivity, resilience and climate change mitigation. CSA-Dx aims to be farmer-centric and decision-relevant. Given these two features, CSA-Dx emphasizes the technology selection process rather than technology evaluation (performance) alone. Technology selection refers to how one decides which farm management option to test from the hundreds of potentially relevant technologies. Technology performance relates to the methods of experimentation including experimental design, indicator selection, data management and storage, and communications.

The CSA-Dx process involves five steps over three phases (figure 1). The first phase, technology selection, includes two steps: (i) alignment and (ii) prioritization. Technology evaluation can be divided into: (iii) experimental design, (iv) indicators and measures and (v) data collection, analysis and reporting. Each step is described in the following sections.

CSA-Dx was designed for people who want a quick orientation to the tools and techniques already available for CSA research. As such, CSA-Dx should be considered a primer for conducting research

on technologies and determining if they qualify as CSA for a specific place and time. It builds on the rich history of participatory action research for other development initiatives (such as sustainable land management, sustainable intensification, landscapes, etc.) and highlights key decision points where researchers or development professionals wish to consider issues that may be CSA-specific. CSA-Dx is not a prescriptive research protocol. It intends to be an integrative tool that helps researchers leverage other resources to gain additional information and refine detailed research protocols for their own investigations.

Figure 1. The steps of CSA-Dx

Technology selection

Technology selection refers to how one decides which farm management option to test. There are hundreds of possibilities ranging from specific fertilizer types to substitutions of feed products for animals to postharvest storage (Dinesh et al. 2017, Rosenstock et al. 2015, FAO 2013). Each technology will have an impact on the productivity, resilience and greenhouse gas balance of the farming system. Because of the diversity of options (and limitations in time and funding), it is necessary to prioritize. The outcome of the prioritization process should be an understanding of the climate hazards of the region, a set of technologies and management practices relevant for farmers and location, and a list of the constraints to production (Bell et al. 2018). CSA-Dx advocates for a two-step process: alignment and prioritization.

Alignment

The first step, alignment, will create a list of technologies and practices that have been identified in relevant policies and programs at the national level. Most countries have multiple policies that outline strategies for agricultural development (e.g., National Agricultural Investment Plans), climate change (e.g., National Climate Change Policy), and programs (e.g., National Reducing Emissions from Deforestation and forest Degradation Strategy). Some governments have come together to create CSA Frameworks Programs ([Uganda](#), [Tanzania](#), [Namibia](#), [Kenya](#), and others), and in other countries multi-stakeholder groups have developed CSA Implementation Guidelines (e.g., [Tanzania](#), [Zimbabwe](#), [Ethiopia](#), [ASEAN Region](#)). These documents provide clear targets and often lists of practices and technologies considered to be of high value and interest.

A quick assessment of the major policies and programs can create a broad understanding of the availability of information and direction of policy (table 1). For example, in Tanzania there are eight relevant agriculture, environment and climate change policies, with multiple CSA-specific plans. These plans contain specific lists of technologies, which can be compared with the agricultural-relevant lists in other policies to provide a first filter of technologies to examine.

Table 1. Policies relevant to CSA action in Tanzania. Key: green: yes/fully; yellow: partially/not always; grey: no/not at all. Source: Nowak (unpublished)

Policy	Policy domain	Are activities in policy relevant for CSA goals?			Does the policy promote CSA measures?	Is CSA mentioned?
		Prod.	Res.	Mit.		
National Adaptation Programme of Action	Climate change	Green	Green	Grey	Yellow	Grey
National Climate Change Strategy	Climate change	Green	Green	Green	Yellow	Grey
National Environmental Action Plan	Environment	Grey	Green	Green	Grey	Grey
Agriculture Climate Resilience Plan	Climate change	Green	Green	Green	Green	Green
Agricultural Sector Development Strategy II	Agriculture	Green	Green	Grey	Yellow	Grey
Intended Nationally Determined Contributions	Climate change	Green	Green	Green	Grey	Grey
Agricultural Sector Development Programme Phase II	Agriculture	Green	Green	Grey	Green	Yellow
Tanzania Climate Smart Agriculture Program	Climate-smart ag	Green	Green	Green	Green	Green
Climate Smart Agriculture Guideline	Climate-smart ag	Green	Green	Green	Green	Green

Prioritization

The second step in technology selection is prioritization. This occurs at a smaller scale, that of agroecology, county/district/province, value chain or farming system. This process will ultimately create a short list of just a few technologies and practices that farmers have identified as relevant to their systems, constraints and climate risks. Choosing which technologies to implement from among the long list developed during the alignment step requires answering four questions:

1. What are the farming activities in the area and their relative importance?
2. What are the constraints to production of the priority farming activities?
3. What are the weather risks for the specific farming systems?
4. What are the primary motivations or barriers for adoption of technology?

Answers to these four questions provide a second filter of the options for evaluation. A range of methods can be used to generate answers to these questions, including key informant interviews or focus group discussions, reviews and meta-analyses of available evidence, and collection of primary farm data. CSA-Dx suggests mixing knowledge systems, using both quantitative and qualitative data, in order to include both farmer preferences and scientific evidence. This increases the probability of being both farmer- and decision-relevant.

Answering these four questions creates a list of ‘best-fit’ technologies to be evaluated in the field. This shorter list can then be prioritized. Appropriate prioritization methods depend on the research constraints, time, funding and experience (figure 2). Examples of participatory approaches to inform practice selection are the Climate-Smart Agriculture Prioritization Framework ([CSA-PF](#)), CSA Rapid Rural Appraisal ([CSA-RA](#)) and CSA Participatory Action Research ([CSA-PAR](#)). Each approach develops lists of site-specific practices with farmers. The CSA Compendium provides a rapid appraisal of the scientific literature (Rosenstock et al. 2015) to evaluate practice potential in a given farming system. The CSA Practical Guide ([CSA-PG](#)) provides another approach to assessing expert opinion. These tools provide comprehensive assessments; data-light versions may be adapted to answer the questions too.

Figure 2. Typology of analytical approaches for prioritizing practices with data, models and expert opinion (farmers and scientists). Links to the tools or resources on these tools can be found in table 2

Special care should be given to the concerns of target populations when prioritizing practices. Interviews, focus-group discussions and workshops are needed to consider the diverse viewpoints of men and women, youth and adults, land-owners and land-renters, etc. A great deal of research is emerging about potential shifts in work burden and household decision-making that accompanies agricultural change and CSA (Collins 2017, World Bank et al. 2015, Jost et al. 2015); thus it is important to get multiple perspectives on issues that will decide the trajectory of research (Jost et al. 2014, ICRAF 2014 for examples of resources).

The outcome of the prioritization process will be a short list of technologies. Equally important will be the systematic justification of why those technologies were selected. Key questions to answer might include the following: Are there no data available on these crop/agroecology/practice combinations? Did farmers specifically identify the technologies for their systems? Were they identified in policy processes as having high potential for resilient agricultural development in the regions?

Table 2. Description of tools available for prioritizing practices. In the “methods” column, HH = Household survey, FGD = Focus Group Discussion and Bio = Biophysical field assessments

Tool	Level	Who participates?	Methods	Time (mo.)	Considers gender?	Quant / Qual?	Select outputs	Strengths	Limitations
CSA Compendium	Farm, program	Scientists	Statistical	0.5	X	Quant	Effect size estimates of practices	Quantitative, speed to completion	Limited to scientific information
CSA Rapid Rural Appraisal (CSA-RA)	Farm	Farmers	HH, FGC, Bio	2	X	Quant	Crop calendars, gender mapping, constraints description	Farmer-centric, biophysical and social	Limited to existing options in the landscape
CSA Prioritization Framework (CSA-PF)	National policy	Decision-makers	HH, FGD	6	X	Qual	Ranked selection of practices	Alignment with national programs and policies	Resource demand
CSA Participatory Selection	Farm	Farmers	FGD	6	X	Qual	Costs benefits, portfolio of practices	Farmer centric and other options	Resource demand
Options x context	Farm	Farmers	HH, FGC, Bio	12	X	Qual	Matrix of practices and constraints	Farmer prioritization and constraints	Resource demand

Tool	Level	Who participates?	Methods	Time (mo.)	Considers gender?	Quant / Qual?	Select outputs	Strengths	Limitations
Rapid Household Multi-Indicator Survey (RHoMIS)	Program	Farmers	HH	1.5	X	Quant	Characterization of farm households	Quantitative, speed to completion, baseline	Doesn't capture preference of practices
CSA Participatory Action Research	Program	Farmers	HH, FGC, Bio	6	X	Quant	Farmer-selected priority practices	Farmer-centric, biophysical and social	Resource demand
CSA–Framework	Farm	Farmers	FGD	3	X	Qual	Scoring of practices	Rapid, farmer-centric, range of indicators	

Technology evaluation

Technology evaluation relates to the methods of experimentation and communication of results. CSA-Dx organizes this evaluation into three steps: (1) experimental design including indicators and metrics, (2) data collection, analysis and interpretation and (3) reporting and outreach. Each of these steps could be described in a book, and each has been the subject of entire university courses. For example, agricultural scientists have been working on efficient approaches to experimental design since at least the late nineteenth century. And, beyond agriculture, a litany of other disciplines including economics, ecology, rural sociology and communications are relevant to CSA technology evaluation. Keeping with the CSA-Dx approach, we do not attempt to provide all the details necessary to design and implement a field experiment. Instead, we link readers to specific resources and highlight emerging opportunities and innovations.

Experimental design including indicators and metrics

Experimental design

The experimental design is the structure of the experiment that will allow technology evaluation. Designs must fit the intended purpose. As such, the research question is the core of the experimental design, and all other facets of the research must be relevant for that question. The experimental design should be as simple as possible while still being able to answer the intended questions. Statistical analysis is paramount, including treatments to be studied and replications. Before the experiment begins, researchers must think through and prepare for the statistical analysis that will be conducted. Only then should site selection and preparation be started.

Many types of experimental designs may be possible for any given question. In the past 20 years, there has been a general shift toward conducting research in farmers' fields rather than on research stations, where most of the research had been undertaken previously. This has made the research more relevant to the farmer because the conditions of the experiment more closely resemble those faced by farmers (including similarities of soil types and the absence of artefacts from previous

experiments). This shift, however, has come at a cost in terms of control and complexity of research trials. While farmer field experiments help build farmer capacity, and there have been some claims of improved adoption rates, the loss in control can compromise experiments when farmers are not engaged, or designs are complicated. Therefore, each type of design has its advantages and disadvantages (table 3) and the optimal choice depends on the purpose of the study.

Table 3: Purposes, strengths and limitation of select experimental designs. Common agronomic designs such as randomized control block and split plot are typical of research stations

Design	Example CSA purpose	Strengths	Limitations	More information
Research station trials	<ul style="list-style-type: none"> • Mechanisms of greenhouse gas emissions • Testing synergies and trade-offs with bundles of technologies 	<ul style="list-style-type: none"> • Control of trial components • Good for complex designs 	<ul style="list-style-type: none"> • May not reflect in-field conditions 	Ministry of Agriculture , Alberta, Canada
Farmer field trials	<ul style="list-style-type: none"> • Simple experiments comparing two or three practices with conventional approaches 	<ul style="list-style-type: none"> • Catalyze adoption • Reflect farmer field condition 	<ul style="list-style-type: none"> • Less control over experiment 	ILRI Training Resources
Mother & baby	<ul style="list-style-type: none"> • Participatory and adaptive research 	<ul style="list-style-type: none"> • Capitalized on both on-station and on-farm 	<ul style="list-style-type: none"> • Resource demand may limit design 	Global Change Laboratory at Michigan State University
Citizen science	<ul style="list-style-type: none"> • Very simple trials such as variety selection 	<ul style="list-style-type: none"> • Large samples size possible 	<ul style="list-style-type: none"> • Simple comparisons • Requires use of technology 	Collaborative Crop Research Program

There is one critical aspect of CSA research under CSA-Dx that separates it from other approaches: The experimental design must include both a technology being evaluated for its climate-smartness and a conventional control. Collecting data on the control provides the yardstick for comparison. Without it, it is not possible to estimate the change with CSA.

Indicators and metrics

Indicators and metrics measure performance. They are the key tools for evaluating technologies against goals and against each other. The CSA-related literature is rife with possible indicators and metrics to collect data that address productivity, resilience and mitigation. This includes items such

as yield, net returns, yield stability, soil carbon, greenhouse gas emission and labour. For a common indicator such as yield, for instance, the metric might be tonnes/ha; for the indicator net returns, the metric would be income/ha (see table 4). A list of more than 400 indicators that others have used can be found in CCAFS [Indicator Tool](#), the FAO's CSA Sourcebook [Monitoring & Evaluation Chapter](#) and the CSA Compendium [Protocol](#). The choice of metrics depends on the research question. With so many metrics, it may be difficult to select. Below is a simple checklist to consider when identifying the most relevant metrics for an experiment:

- There is at least one variable across each CSA pillar
- The metrics are sensitive to an identified risk (such as drought or soil moisture)
- The variables respond to the goals of the farmers or community (such as resilience to weather leading to yield stability over time)
- The variables and related measures are time-bound
- The resources available allow measurement of performance with sufficient quality
- The framework includes field-level variables as well as household data, where possible and relevant

For the most part, technology evaluation with CSA-Dx is interested in field-level changes. Thus, CSA-Dx must take a pragmatic approach to measuring resilience, using metrics that imply some sort of biophysical, economic or social resilience without directly measuring it. This include indicators such as soil carbon, which increases the buffering capacity to droughts, and resource-use efficiency, which improves the economic resilience of systems by maintaining production with less. However, CSA research may sometimes be interested in measuring resilience directly. A number of tool are available to guide selection of indicators in such cases (box 2).

Box 2. Including household-level indicators when evaluating CSA technologies

Indicators of CSA can be measured at various scales: plot, field, farm/household, landscape and beyond. CSA-Dx typically measures species and field effects. Resilience, however, is often an emergent property at the household or farm level. Sometimes it is helpful to consider metrics of household level such as the Coping Strategies Index, which measure how people adapt to food insecurity, or the Food Insecurity Access Scale. The CCAFS Climate-Smart Village Monitoring [Plan](#) outlines many potential metrics at the household level. And the Rural Household Multi-Indicator Survey ([RHoMIS](#)) provides a flexible tool to put household-level indicators into action using open-source tools. It is worth considering how a selection aligns with major development initiatives. The CCAFS Indicator Tool compiles indicators from major donors that align with CSA into a searchable [spreadsheet](#).

Data collection, analysis and interpretation

Data collection

When people first think about experimentation or science, typically the first thing that comes to mind is data collection, analysis and interpretation. The CSA-Dx process emphasizes that there are many important steps before that. Sufficient time and thought in the planning process ensures that data collection, analysis and interpretation—the nuts and bolts of the scientific process—run more smoothly.

Data collection requires unique protocols and procedures for each metric selected. Each should be clearly laid out in both methods and timing. Data collection protocols should conform to the most up-to-date information on methods, which are always changing as scientists challenge errors and overcome uncertainties in the methods. By searching online (e.g., Googling by key terms), it is possible to find existing protocols for many metrics (table 4). But given the ubiquity of such protocols in research, it is unfortunate that they are not more readily available. The situation, however, may change in the near future as the move towards reproducible science encourages scientists to post protocols and data online.

Protocols are simply detailed explanations of methods. The level of detail extends far beyond what is written in scientific papers. Protocols should contain equipment lists, step-by-step instructions, forms necessary for recording measurements in the field, timelines and more. Data collection protocols, however, do not typically outline the analysis methods planned. These have usually been decided upon or at least proposed during the planning stage. We recommend, however, that

protocols include a minimum level of detail of the intended analysis methods in order to provide transparency.

Table 4. Table of select indicators and metrics and a selection of protocols/standards for implementation

Indicator	Metric	Example protocols
Productivity		
Yield	tonnes/ha	SAMPLES Yield Estimation
Net returns	\$/ha	CIAT Cost Benefit Tool ¹
Land equivalent ratio	LER	ASB Lecture Notes 8, 10
Resilience		
Yield stability	Coefficient of variation (CV), environmental variation	UN Food and Agriculture Organization
Resource use efficiency	Feed conversion efficiency (g/g), nutrient use efficiency (N in product/N applied), water use efficiency (kg/mm)	International Plant Nutrition Institute
Biodiversity	Species abundance	VBioindex , Healthy Farm Index
Soil health (soil C, pH, bulk density, etc.)	Tonnes carbon/ha, pH, g/kg	ICRAF Land Degradation Surveillance Framework
Mitigation		
Carbon sequestration in soils and biomass	Mg C/ha, Mg C/Mg soil	SAMPLES Biomass C , ASB
Emissions	CO ₂ , N ₂ O, CH ₄ /yr	SAMPLES Soil Emissions , Global Research Alliance
Fertilizer use	kg N/ha	Rural household Multi-Indicator Survey (RHoMIS)
GHG balance	tCO ₂ -eq	Cool Farm Tool , EXACT
Emissions intensity	tCO ₂ -eq/kg product	CCAFS Mitigation Option Tool

¹Publically available in 2018

There have been many advances in the collection and analysis of data, largely because of the expansion of personal computing power. With the recent rise in mobile technologies and platforms to collect and compile data, there are few reasons to stick with paper surveys or data collection methods. Both open-source and proprietary options are available (see [Open Data Kit](#), [Magpi](#), [SurveyCTO](#)). Digital data collection offers many advantages, including greater accuracy, reduced time in preparing data for analysis, enhanced security and reduced chance of loss. Whether digital or paper-based data collection is used, however, it is imperative to keep close track of activities in the field in real time, so that as many details as possible are captured.

Data analysis

The type of analysis should be decided before the experiment starts. The reason for this is simple: the data collected determine what type of analysis is possible. Common statistics used in CSA research include analysis of variance, multiple linear and non-linear regression, binomial regression, and much more. Information on these and many other types of statistical analyses can be found online. Researchers unfamiliar with statistics should search out skilled advisors, and also make a study of the topic. Statistics are the backbone of quantitative science and therefore a critical skill to cultivate.

Statistics recently has become intertwined with computer programming and in some ways with data science. Open-source programs such as [R](#) and [Python](#) are becoming the programs of choice, except for economists who still use STATA. For mapping, tools such as [QGIS](#) are quickly emerging as open-source solutions. R and Python are programming languages that require writing computer code to execute arguments. The benefit of the open-source languages is that they are supported by large communities of users that provide useful online resources (such as [Quick-R](#), [R for Data Science](#)). In addition to online resources, there are courses available in many areas to assist beginners.

Some of the most important analyses typically conducted in CSA research involves trade-offs and synergies among outcomes. There are many ways to analyse this topic (for reviews see Van Wijk et al. 2016, Kanter et al. 2016), ranging from econometric optimization models to participatory analysis involving mapping and game playing. Each of the approaches has advantages and disadvantages, so care should be taken when selecting among them (table 5).

Table 5: Strengths and limitations of the different approaches for analysing trade-offs in agricultural systems ('A' is the actual or current state in the scientific literature, while 'P' is the potential usefulness of a technique to assess a certain aspect of trade-off analyses). '+' represents a strength and '-' a limitation.

Source: [Wijk et al. 2016](#)

Aspect	Research Approach									
	Empirical		Econometric		Simulation		Optimization		Participatory	
	A	P	A	P	A	P	A	P	A	P
Integration of interdisciplinary content	-	+	+	+	-	+	-	-	-	+
Assessment across different time horizons	-	-	+	+	+	+	+	+	-	+
Assessment across spatial scales and integration levels	-	+	-	+	+	+/-	+/-	+	-	+
Takes into account qualitative information	-	+	-	-	-	-	-	-	+	+
Appropriate representation of uncertainty	-	+	-	+	-	+	-	+	-	+
Identification of possibilities to alleviate the observed trade-offs	-	-	-	-	+	+	+	+	-	-
Ability to deal with real-life system complexity	+	+	-	+	-	-	-	-	+	+
Applicability to real-life decision-making	+	+	+	+	-	-	+/-	+/-	+	+

Arguably the most straightforward trade-off analyses involve empirically examining the bi-plots of the indicators. These analyses describe the system in a simple and visual way, allowing clear reporting of the data and outcomes in ways that are relevant and interpretable for a variety of users (figure 3). There are, however, different approaches as well, and it is important to match the analytical approach to audience needs and interests.

Figure 3. Theoretical biplots representing multi-dimensional relationships among the three pillars. Top-right quadrant are win-win (synergies), top-left/bottom-right are win-losing (trade-offs) and bottom-left is lose-lose (bad ideas). Solid vs open circles represent different technologies (e.g., CSA and conventional practice). Circles could represent farmers or different metrics of CSA, etc. Modified from Lamanna (unpublished).

Not all CSA research requires the analysis of trade-offs. Researchers also may aim to look at the impact of the technologies on individual CSA outcomes or the synergistic effects of applying multiple technologies rather than one technology alone. There are few rules, except that the research needs to collect information on indicators and metrics of at least two of CSA's three pillars—production, resilience and mitigation. While that may seem like a fairly low threshold for acceptability, when combined with conducting research on both conventional and improved practices, it still represents a dramatic departure from historical research norms.

Data interpretation & visualization

Data visualization is the presentation of information. This can be done either in tabular form or in figures and pictures. The goal is to present data simply and effectively. The reader should not have to search for the meaning and the author should not manipulate the information in any way.

Data reporting and visualization depends in part on convention and in part on personal style. When reporting in scientific papers, results are often expected to be presented in certain ways. Deviation from convention may leave reviewers and readers searching for information. It is best to view other papers in the journal or on the topic to see how they present results. That is not to say there is no room for innovation in scientific publishing, only that one must consider the options cautiously.

Reporting for other types of outlets allows greater freedom of expression. In the past few years, many blogs and books have been produced on best practices for data visualization. The key source remains Tufte's [*The Visual Display of Quantitative Information*](#), but many other guides are available. It may be best to search around and be inspired by one of the most exciting fields in science. Here are a few helpful websites: [Information is beautiful](#), [VizCandy](#), [Flowdata](#) and [DuelingData](#). Appendix II offers an example of the type of data visualization possible using information generated from CSA-Dx.

Communications

Audience-specific

How you package research results only matters whether you care if anyone reads them. For example, farmers do not usually read scientific papers, and policymakers and program developers rarely do either. However, journal articles are the currency of science and form the basis for much evidence-based decision-making. Since CSA research is relevant and of interest to a wide range of people, results need to be communicated in an equally diverse number of ways. Materials should be prepared for specific user groups (audience-specific), in their language (culturally appropriate) and delivered through their media (appropriate channels / platforms). Creating targeted communications requires an understanding of: (1) the audiences' interests, (2) the messages of the research, (3) timing of key events and (4) appropriate packaging and delivery tools (table 5).

Follow, tweet, like, lead

There are other communications strategies besides development of knowledge products (e.g., briefs, journal articles). Today, almost all development agencies, research institutes, universities, many practitioners and even government ministries have social media presence. What's more is that social media are no longer the spaces where people only share what kind of sandwiches they like, or the places they visit: elections have been run (and some say, won) on Twitter, revolutions have been televised and socialised (Tahrir square), foreign policy debated and polled. Social media is not simply a nice to have – it's also where many real-world discussions take place. Using social media as vehicles for CSA communication can be extremely successful and allow for reaching various audiences, at a low cost. Some examples of potential avenues for communicating CSA through social media, are: (1) Following conversations of kindred organisations, and participating in trending discussions; (2) Contributing evidence-based snippets (tweets) and publications (post); (3) Expressing your relevance in topical conversations (like); and (4) Leading industry thought by publishing research on social media (in addition to other channels in the scientific community – i.e. research / scientific journals). But these are just a few suggestions. This space is rapidly evolving so it is an exciting place to innovate and experiment in communications.

Table 5. Examples of communication plan that illustrates targeting knowledge products for audiences.

Source: Modified from Ng'endo (unpublished)

Target audience	Type of product	Types of messages	Why?
Cross-cutting audience	Strategy document	Reference document identifying project's communications objectives, plan of activities, relevant audiences, channels, resources and projected timelines	Internal document for setting strategy and for monitoring and evaluation of communication efforts
	National/local-language newspaper article	Implementation and outcomes of CSA practices timed for key periods (e.g., during annual farmer's day)	Provides visibility of information in formats widely read and in appropriate languages
Farmers	National/local - language brochures	Brief background on CSA technologies and stepwise instructions on implementing CSA technologies	Consistent and easily updateable branding for messages that are consistent with farmers' needs
Ministry officials	Posters & policy briefs	Prioritization among different CSA practices	Short (one page), easily digestible and interpretable information that can be shown in public spaces
	Video/photo essays	Video logs from field research	Capacity building and outreach about activities ongoing in the field sites
Researchers	Scientific protocols	CSA experimental methods	Capacity building of national agricultural research staff
	Scientific conference proceedings	Oral or poster presentation	Validation and distribution of findings to scientific audience
	Journal publications	Multi-objective impacts of CSA	Scientific credibility and visibility of work

In short, there are many options for communicating results such as social media, workshops, special events, workshops, scientific conferences, leveraging social networks such as farmer-to-farmer groups or cooperatives, and the development of specific curricula and capacity building activities. The key point is to take communications seriously, it is the mechanism to effect change.

Conclusions/recommendations

CSA-Dx provides a primer intended to quickly orient users to the issues and tools relevant for research on climate-smart agriculture. It is important to remember that this is just a step in a research planning process. As a follow up, researchers should drill down and identify the specific instruments and resources needed to carry out the work. It is impossible to over-emphasize the need to plan and take into account all the things that might go wrong. Even then, the unexpected will happen, requiring adjustments on the fly. However, working through the CSA-Dx and consulting the linked resources will leave researchers prepared to modify and continue the work in a confident way.

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¹ Also, check all hyperlinks embedded in text.

Appendix I. What is the evidence-base for climate-smart agriculture in Tanzania?

Info Note

What is the evidence-base for climate-smart agriculture in Tanzania?

Christine Lamanna, Anthony Kimaro, Aslihan Arslan, Caitlin Corner-Dolloff, Todd S. Rosenstock

MAY 2018

Key messages

- Evidence exists to support CSA programming on the most widely cultivated crops (e.g. maize), and most common agricultural practices (e.g. fertilizer addition) in Tanzania
- However, products and places central to rural livelihoods such as livestock, coastal drylands, and humid regions near Lake Victoria are understudied.
- Data on how CSA changes agricultural productivity is widely available (77% of the data), while 20% of the data is related to resilience indicators, and only 3% deals with greenhouse gas mitigation outcomes.
- Practitioners should draw on this rich evidence base for CSA in Tanzania, while also prioritizing the generation of evidence for understudied products, agroecologies, and practices.

Climate-smart agriculture in Tanzania

The agricultural sector in Tanzania provides livelihoods to nearly three-quarters of the population and contributes nearly 95% of the country's food supplies (URT MALF 2017). However, climate change and land use change threaten food security through changing crop suitability, more frequent extreme events such as floods and droughts, increased pest and disease outbreaks, and land degradation (Figure 1). In response to food security and climate change challenges, the Government of the United Republic of Tanzania adopted the Climate-Smart Agriculture (CSA) Programme for Tanzania (2015-2025) in 2015 and launched the Tanzania Climate-Smart Agriculture Alliance in 2018. The CSA Programme aims to promote and enable the adoption of agricultural practices that achieve the three pillars of CSA: 1) sustainably increase agricultural productivity, 2) increase the resilience of agricultural systems, and 3) mitigate the effects of climate change where possible (FAO 2010).

Achieving widespread adoption of CSA practices requires that options be well-suited to the local agroecological and socioeconomic conditions, in order to deliver the multiple benefits promised by CSA. Decision-making for CSA requires evidence of what works where and for whom in order to make the best possible investments. But what information on CSA in Tanzania is available? And does that information match the actual farming systems that the population relies on?

In this brief, we compare the availability of scientific evidence of the impact of CSA management practices on the crops, livestock, and agroecologies of Tanzania with what crops Tanzanians are actually growing and where. The goal of this brief is to provide an overview of the evidence base for CSA in Tanzania: what options have been studied, in what agroecosystems, and what outcomes have been measured. By comparing the data with the composition of smallholder agriculture in the country, we identify key gaps in this evidence base that can serve to guide future research on CSA in the country.

Figure 1. Farmers in dryland areas of Tanzania, such as this village near Dodoma, will be subjected to increasingly erratic rainfall with climate change, making adoption of CSA a top priority. Photo credit: C. Schubert (CCAFS).

What is the evidence on CSA in Tanzania?

Using a systematic review protocol (Rosenstock et al. 2015), we searched for evidence in the peer-reviewed literature on over 100 potential CSA practices and more than 50 potential outcomes in Tanzania. For a study to be included in the resulting database, the TZ CSA Compendium, it had to contain primary, quantitative data on the change created by a CSA practice relative to a control (more conventional practice) for an outcome indicator relevant to at least one of the three CSA pillars: productivity, resilience, or mitigation (see in depth results in Lamanna et al. 2015).

Through our systematic review, we found 58 peer reviewed studies on potential CSA practices in Tanzania that fit our inclusion criteria. Of these, a little over half (55%) were conducted at research stations, while the other half were done in farmers’ fields. While these studies have been conducted across the country, studies are generally clustered in a few locations and agroecological zones (Figure 2). In particular, the semi-arid zones around Dodoma and Morogoro, the Southern Highlands of Mbeya, and the Usambara Mountains of Kilimanjaro and Tanga regions have been well studied. This is not necessarily surprising as these areas have benefited from regionally-based agricultural research institutions in the area.

Figure 2. Location of studies on potential CSA practices in Tanzania in red, plotted on a map of the density of agricultural households in each of the 31 regions (URT MALF 2008).

The Tanzanian Agricultural Sample Census reports that smallholders produced 54 crops and 14 livestock products in the 2008 agricultural sample census (URT MALF 2008). While our database contains data on 28 of these agricultural products, not all of these products have been studied equally (Figure 3). Cereals make up the majority (60%) of products studied, with maize

representing a full 55% of the database (and over 90% of the data on cereals). Animal-sourced products such as meat and milk make up only about 5% of the data.

Thirty-eight (38) different potential CSA practices have been studied in the TZ CSA Compendium. Fertilizer addition to crops is the most studied practice, with inorganic fertilizers comprising 34% of the data and organic fertilizers such as manure comprising a further 11% (Figure 4). Diversification practices including alleycropping with trees, green manure rotations, and intercropping are also represented in the dataset, as are soil water management technologies such as reduced tillage, *fanya juu/fanya chini*, zai pits, and mulching. Of the data on practices, 57% is from practices done in combination; that is, multiple CSA options implemented concurrently.

Figure 3. Representation of agricultural products in the TZ CSA Compendium. Cereals make up the majority of the dataset, while other nutritionally important products such as legumes (9%), vegetables (5%), and meat represents a much smaller proportion of data.

Figure 4. Distribution of data in the TZ CSA Compendium by practice/technology.

CSA is based on the idea that appropriate agricultural practices can deliver multiple benefits, particularly across the three pillars of productivity, resilience, and mitigation. The TZ CSA Compendium contains data on 10 different outcomes of CSA and 19 specific indicators. However, the majority of the data comes from the productivity pillar: 77% of the data is on a component of productivity, such as product yield or net returns, and nearly all of this data is on yield (Figure 5). Only 20% of the data is related to resilience indicators, such as soil health or input use efficiencies, while only 3% deals with mitigation outcomes such as GHG fluxes or soil carbon stocks. The majority (72%) of studies in the TZ CSA Compendium contain data on only one pillar, while 26% have measured outcomes in two pillars (typically productivity and resilience). Only one study in our dataset addressed all three pillars of CSA.

Figure 5. Distribution of data in the TZ CSA Compendium across the three pillars of CSA, and their individual indicators.

Key Knowledge Gaps

Compared to other countries in Africa, Tanzania ranks 5th in terms of the number of agricultural research studies on potential CSA practices and technologies that have been published. This relative wealth of agricultural research provides a rich evidence base for decisions. Yet there are still some key gaps in the evidence base, particularly when we compare the available evidence to actual Tanzanian farming systems. In this section, we compare the distribution of data available on CSA from the TZ CSA Compendium above with the characteristics and distribution of Tanzanian smallholder farming households, based on data from the latest Tanzanian Agricultural Sample Census (URT MALF 2008).

Products: The majority of smallholder farmers (69%) in Tanzania grow maize, however this varies from more than 95% of farmers in Tabora and Iringa regions to less than a third of farmers in coastal regions such as Dar es Salaam and Pwani (URT MALF 2008). The majority of CSA research in the country has been done on management options for maize, and thus creates useful information for the majority of farmers in the country. One

key mismatch between the available data and actual farming systems, though, is with **livestock** (Figure 6a). About one-third (31%) of smallholder farmers in Tanzania keep livestock along with their crops, varying from a low of 11% in Lindi to a high of 53% in Singida (URT MALF 2008). However, only 5% of agricultural research in Tanzania has been conducted on livestock, and even less on crop/livestock integration. While the majority of the livestock data we do have is on cattle, small stock and chickens are important livestock species particularly in the more coastal regions (in Lindi <2% of households have cattle).

Figure 6: Comparison of coverage of a) agricultural products and b) practices in the database (% of data) with frequency of that product or practice being utilized in Tanzania (% smallholder households). Positive values mean that product or practice is relatively overstudied, while negative values mean it is relatively understudied.

Key crops that are critical to food and nutrition security in Tanzania are under-represented in the literature on CSA. **Beans**, which are the second most important crop in TZ grown by 30% of farmers, and provide key dietary protein for many Tanzanians, only make up 9% of the database. Additionally, **starchy roots and tubers** such as cassava, a potentially important crop for increasing food security in times of drought, are understudied.

Practices: Compared to their prevalence in Tanzania, the addition of fertilizers and irrigation are well studied (Figure 6b). Contrastingly, nearly every household in Tanzania practices some form of **crop storage** (93%), but only one study in our dataset addressed crop storage, accounting for <0.1% of the data in the dataset. Similarly, nearly all households report soil erosion problems in Tanzania (91%), but specific practices used to combat erosion such as **contouring** make up less than 5% of the data available. Thus, there are potential CSA practices with wide adoption potential and impact that have been neglected in formally-published agricultural research in the country.

Agroecological Zones: When we compare where agricultural research has been conducted with where smallholder farmers live (Figure 2) and the corresponding agroecological zones, some key gaps emerge. One of the most densely populated areas of Tanzania is the region surrounding **Lake Victoria** in the Northwest. Nearly 26% (over 1.5 million) of Tanzania's smallholder farming households lives in the regions bordering the lake, but less than 10% of the research in our database took place there. Not only does this region support a large proportion of Tanzania's households, it also has unique agroecologies, such as humid forest supporting highland perennial agriculture, and sub-humid savannahs, which are the country's main region for root and tuber production.

Coastal communities are also underrepresented, despite the fact that they support nearly 20% of the country's smallholder farmers. Although there is some research on the uniquely coastal spice agroforestry, the most common staple crops grown in sub-humid coastal agroecosystems are unstudied. In Zanzibar the most common agricultural crops are rice, sweet potato, maize and cassava in that order. Coastal areas also provide unique agricultural systems, such as seaweed cultivation, which are important for income, diversification and nutrition, that have not been given research attention.

Outcomes: Finally, there are also gaps in our knowledge of what outcomes can be expected from implementing CSA in Tanzania. Although **mitigation** of climate change through reduced emissions or carbon storage is one of the three pillars of CSA, there is virtually no evidence on how various CSA practices *change* greenhouse gas emissions, soil carbon stocks, or aboveground carbon storage in-country (but see Kimaro et al. 2015 for an example). While we have ample evidence of how CSA options influence yield (particularly for maize), there is little accompanying **economic information**, which is critical to building business models for successfully scaling up CSA adoption. Lastly, there is a lack of data on the impact of CSA adoption on gender-differentiated outcomes such as labor, income, or decision-making, which can be critical to improving food and nutrition

security and increasing the resilience of smallholder households to shocks.

Conclusions and policy implications

The results of this exercise show that there is a wealth of information on potential CSA practices in Tanzania. However, this evidence base isn't comprehensive. In particular, key gaps exist for livestock, non-cereal crops, humid and coastal agroecologies, and crop storage. Agricultural research and development in the country should consider expanding activities in these sectors and regions in order to build a more complete picture of climate change and agriculture in Tanzania.

Further Reading

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Appendix II. CSA X-Ray for Tanzania

Bare bones evaluation of climate-smart
agriculture practices & technologies

CLIMATE SMART AGRICULTURE IN TANZANIA MAIN MESSAGES

What is and what is not climate-smart agriculture (CSA)? That existential question sparks debate, complicates implementation and fractures the development community. CSA X-rays provide a detailed analysis of what science and scientists tell us about the 'climate-smartness' of proposed CSA interventions. Each section contains an infographic that illustrates the potential impact of the intervention on outcomes when changing practices¹.

Key messages for the CSA X-ray for Tanzania are:

<i>Productivity</i>	Most CSA practices increase crop yields in Tanzania, when compared to conventional practices, with the exception of deficit irrigation for maize. Yield gains are typically substantial, from 30-125% increase in mean yield, with gains in rice yields under system of rice intensification (SRI) showing the largest gains. Impacts of changing to CSA practices on farmer income are variable dependent on crop and practice, but generally positive.
<i>Resilience/ Adaptive Capacity</i>	Many CSA practices improve physical resilience of farms by improving soil health and reducing erosion, creating more sustainable productivity. However, some practices such as reduced tillage and mulching may increase labour demands, particularly for women.
<i>Mitigation</i>	CSA practices in Tanzania increase organic carbon in the soil and thus offset GHG emissions. However, increases in soil carbon may also increase soil respiration, contributing to climate change.
<i>Climate Risks</i>	Because of the positive affects on soil physical properties, many climate-smart practices have potential to mitigate many of the precipitation and seasonal affects of climate change. In particular, water harvesting techniques can ameliorate threats from heavy rain, drought tolerant varieties can help with warmer temperatures and intra-seasonal droughts, and residue retention, reduced tillage, and deficit irrigation can address lower and unpredictable rainfall.
<i>The Business Case</i>	Most CSA practices increase economic returns to land and labour relative to conventional practices. However, there are also risks of decreases in yield or income with each practice that need to be considered with the potential reward.
<i>Scaling up</i>	Adoption rates for CSA practices vary widely in Tanzania, with some practices already in high use such as intercropping, while other potentially beneficial practices such as green manure, agroforestry and improved varieties lagging behind.
<i>Barriers to adoption</i>	The factors affecting adoption of CSA are inconsistent across studies in Tanzania. Many of factors have both positive and negative impacts depending on the study and few are universally influential in the same direction. However, wealth, land tenure, and access to extension agents consistently increase adoption rates.

¹ X-rays were designed to print as either 4-page leaflets that include key messages and hints on interpretation or 2-page briefs.

CSA X-RAY

Bare bones evaluation of climate-smart agriculture practices & technologies

CSA IN TANZANIA

FARM LEVEL MANAGEMENT PRACTICES FOR CROPS TO IMPROVE PRODUCTIVITY, RESILIENCE TO CLIMATE CHANGE, AND PROVIDE MITIGATION CO-BENEFITS IN TANZANIA

PRODUCTIVITY

Percent change in yield or income from the CSA practice relative to a baseline practice for all crops combined. Dashed lines represent the mean percent change, and bar length shows the 95% confidence intervals around the mean.

CSA TECHNOLOGY

SYSTEMS	NUTRIENT MANAGEMENT	CROP MANAGEMENT	SOIL MANAGEMENT	WATER MANAGEMENT
Agroforestry (af)	Inorganic Fertilizer (if)	Improved varieties (iv)	Green Manure (gm)	Drip Irrigation (di)
System of Rice Intensification (sri)	Organic Fertilizer (of)	Intercropping (ic)	Mulching (m)	Zai pits (zai)
		Crop Rotation (rot)	Reduced Tillage (rt)	Rainwater Harvesting (uh)
		Postharvest Storage (ph)		

MITIGATION

Heat map showing effects of CSA practice on greenhouse gas emissions, carbon stocks, and emissions intensity.

RESILIENCE

The magnitude (size of bubble), sign (position of bubble), and amount of evidence (fill of bubble) for impact of CSA practices on resilience indicators. Color of the bubble indicates the type of resilience.

CLIMATE RISKS

The relative reduction in climate risk by using CSA practices. Larger bars indicate greater mitigation of the climate risk identified by color. Practice codes are the same as in CSA TECHNOLOGIES.

BUSINESS CASE

(A) Change in economic performance relative to the conventional practice, (B) Semi-quantitative assessment of risk (chance of decrease in yields) vs. reward (mean increase in yield) for various crops under CSA practices identified by code (C) Net returns (Millions of TZShs/ha) on investment over time.

SCALING UP

CURRENT ADOPTION

Current mean rates of adoption of CSA practices in Tanzania.

BARRIERS TO ADOPTION

Impact on adoption shows the proportion of studies where farm and household characteristics have a positive (to the right) or negative (to the left) impact on adoption. Significance shows the number of studies where that factor had a significant (filled bar) or insignificant (open bar) impact on adoption.

MORE INFORMATION

The CSA X-ray is based on published data and expert opinion. Sources used for each indicator can be found on the 'CSA X-ray' repository on Harvard's Dataverse. We thank the CGIAR Research Program on Climate Change, Agriculture, and Food Security for funding the Partnerships for Scaling Climate-Smart Agriculture (P4S) Project that conceived of the X-rays and the United States Agency for International Development for their support of staff executing the vision.

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READING THE X-RAY

TECHNOLOGIES

Description of the CSA technologies covered. Each has an abbreviation that will be used throughout the X-RAY.

PRODUCTIVITY

Percent change (%) in productivity indicators under CSA technologies as compared to conventional practices. The vertical line at 0% represents no change in productivity. In each colored bar, the mean percent change is shown as a dashed line, and the width of the bar represents the 95% confidence interval around the mean for percent change in productivity. The position of the bar indicates the magnitude of change and the size the bar is indicative to the variability for the crop and practice.

MITIGATION

Change in greenhouse gas emissions and carbon stocks under CSA shown as a heat map. Warm colors (orange to purple) mean an increase in climate forcing or lower mitigation potential, while cool colors (green to blue) mean a decrease in climate forcing or higher mitigation potential. Where there is no expected change or no data, the square is empty. Data based on published literature and expert opinion are shown for soil carbon, aboveground biomass, soil GHG fluxes, and emissions intensity (emissions per unit product).

RESILIENCE

Impact of CSA practices on indicators of physical (blue), economic (green), and social (orange) resilience. The size of the bubble relates to the magnitude of change, for example a larger change in that indicator under CSA. The location of the bubble on the horizontal axis indicates the direction of the change. Bubbles to the right of the dotted line show improvement in resilience, while bubbles to the left decrease that proxy for resilience. Bubbles sitting on the dotted line mean that there is conflicting evidence – sometimes that resilience indicator improves and sometimes it doesn't. The fill (shading) of the bubble indicates how much evidence is available. Open bubbles mean the change is theorized but no evidence is available, shaded bubbles mean some evidence is available, and filled bubbles mean a lot of evidence is available.

CLIMATE RISKS

Around the circle are five key climate risks potentially addressed by CSA. For each CSA practice and climate risk combination, the height of the bar indicates how well that practices addresses that climate risk. Higher bars mean better mitigation of climate risk.

BUSINESS CASE

- (A) Percent change in economic performance relative to the conventional practice for various indicators. Increases in economic performance are positive bars, whereas decreases in economic performance are negative bars.
- (B) Risk vs. Reward for CSA practice/crop combinations. Reward relates to the change in yield is on the vertical axis, and risk relating to the chance of decrease in yields is on the horizontal.
- (C) Illustrative economic performance of CSA practices relative to a control over time.

SCALING UP

For current adoption, each person icon represents a number of small farmers who have adopted that particular practice in that location. In Barriers to Adoption, each farm and household characteristic (listed in grey) has an associated impact on adoption (left orange panel) and significance (right blue-green panel). Impact on adoption panel shows the proportion of studies where that factor positively (to the right) and negatively (to the left) affected adoption. Interesting to note bars that cross the vertical center line (positive and negative effects depending on context) and the size of the bar indicating how many studies have included that factor. The significance panel shows the number of studies conducted on that factor (open bar) and the number where that factor significantly impacted adoption (filled bar).

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