Gates Agronomy Grant Learnings: Final Report




December 2020

Submitted to:
The Bill and Melinda Gates Foundation
440 5th Avenue N
Seattle, WA 98109

Submitted by:
Abt Associates
6130 Executive Boulevard
Rockville, MD 20852

About This Report

This is the Final Findings Report, which describes the final findings from the agronomy grants evaluation for the Bill and Melinda Gates Foundation.

Authors

Maria Boyle, Ben Johns, Marius Meijerink, Russ Jones

Suggested Citation

Boyle, M., Johns, B., Meijerink, M., & Jones, R. (2020). *Gates Agronomy Grant Learnings: Final Report*. Report prepared for the Bill and Melinda Gates Foundation. Abt Associates. Available at: https://gatesopenresearch.org/

Abt Associates, Inc. | 6130 Executive Boulevard | Rockville, MD 20852

Acknowledgement

This report was written by Maria Boyle, Marius Meijernik, Ben Johns, and Russ Jones, with support from other members of the evaluation team.

We would like to thank many individuals and organizations who helped make this study and report possible. At Abt, we thank Lauren Rosapep and Lauren Olsho for providing valuable leadership and feedback on the report. Joeva Rock as our desk review consultant provided expert insights into the work of the grantees. Tresa Kappil demonstrated great organizational skills in managing and coordinating the remote interviews and interview coding staff. Thanks to Jillian Oulette and Cristina Booker for their diligence in summarizing findings for several grantees, Alex Mijares for her oversight of the interview coding and analysis, and our numerous team members who carefully coded the work of the grantees. Thanks to René Nutter for conducting a number of interviews. We also thank previous members of the study team Abigail Conrad and Tulika Narayan for their earlier contributions to the development and design of the evaluation. Thanks to Alexa Smith-Rommel for editing, and Jessica Kerbo, Jeff Smith and Charmayne Walker for producing the report.

Notably, we thank the staff from the Bill and Melinda Gates Foundation for their support of the evaluation. In particular, Christian Witt, Julianna Drinan, and Amy Sherwood provided key guidance and feedback on executing the evaluation and producing the report.

Finally, a tremendous thank you to grantees and their partners and stakeholders who provided us with their time and valuable insights: N2Africa, CSISA, SBPEA, TAMASA and ACAI. Without them, this study would not have been possible.

CONTENTS

Abbreviations

ACAI	African Cassava Agronomy Initiative
APS	Agronomic Panel Survey
ATARI	Agricultural Technology Application and Research Institutes (India)
BARI	Bangladesh Agricultural Research Institute
BMGF	Bill and Melinda Gates Foundation
BNF	Biological nitrogen-fixation
BUK	Bayero University Kano (Nigeria)
BXW	Banana Xanthomonas Wilt disease
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CND	Computational Nutrient Diagnosis
CSISA	Cereal Systems Initiative for South Asia
CWMP	Cassava Weed Management Project
DOA	Department of Agriculture
DRIS	Diagnosis and Recommendation Integrated System
DSR	Directly seeded rice
DST	Decision-support tools
ETM+	Enhanced Thematic Mapper Plus
EUP	Eastern Uttar Pradesh
FUNAAB	Federal University of Agriculture Abeokuta
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPGs	Global public goods
GPS	Global Positioning System
IAR	Institute for Agricultural Research (Nigeria)
ICAR	Indian Council of Agricultural Research
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
ISFPM	Integrated Soil Fertility and Pest Management
IWM	Integrated Weed Management
KVK	Krishi Vigyan Kendra (agricultural extension)
LDS	Landscape Diagnostic Survey

M&E	Monitoring and evaluation
MEL	Monitoring, Evaluation, and Learning
MRT	Mechanical rice transplanting
MSA	Maize Seed Area (app)
MVS	Maize Variety Selector (app)
NARO	National Agricultural Research Organization (Uganda)
NARS	National Agricultural Research System
NE	Nutrient Expert (decision tool)
NGO	Non-governmental organization
NOT	Nutrition omission trial
OCP	Fertilizer company
ODK	Open Data Kit
PAD	Precision Agriculture for Development
PIRS	Performance Indicator Reference Sheet
PPP	Public private partnership
QUEFST	Quantitative Evaluation of the Fertility of Tropical Soils
R&D	Research and development
RQ	research questions
RCT	Randomized Controlled Trial
SAA	Sasakawa Africa Association
SBPEA	Sustainable Banana Productivity in East Africa
SIS	Soil Intelligence Systems
SLC	Scan Line Corrector
SMS	Short Message Service
TAMASA	Taking Maize Agronomy to Scale in Africa
USAID	United States Agency for International Development
ZT	Zero tillage

Executive Summary

The Bill & Melinda Gates Foundation (BMGF) invested over $300 million between 2008 and 2019 in research grants under its Soil Health and Agronomy portfolio, which supports the scaling of solutions to increase productivity-led growth in the smallholder sector and spur rural sector economic development. The strategic focus of the grant projects has evolved to build on work achieved through previous grant projects.

To date, the foundation had not completed a comprehensive assessment of its agronomy portfolio, and therefore contracted with Abt Associates to do so. This strategic assessment included five agronomy grant projects, which are a subset of the foundation's agronomy portfolio. These agronomy grant projects span over a decade, cover diverse geographies in both sub-Saharan Africa and South Asia, and work across different cropping systems. These grant projects are Cereal Systems Initiative for South Asia (CSISA) Phase 2 (2012–2016) and 3 (2015–2020); N2Africa Phase I (2009–2014) and Phase II (2013–2019); Taking Maize Agronomy to Scale in Africa (TAMASA; 2014-2019); African Cassava Agronomy Initiative (ACAI; 2015–2020); and Sustainable Banana Productivity in East Africa (SBPEA; 2016–2020).

The foundation selected these projects because they share several characteristics that allowed an assessment of common challenges, successes, and opportunities:

- Their research agendas are informed by demand-driven use case development.
- Their research designs are based on sound scientific principles, with strong geospatial components in both research and implementation.
- They have focused on alliances with scaling partners from the beginning.
- They employ user-centric (primarily for farmers and extension agents) and appropriate tool development for agricultural advisory services.

After a preliminary review of project activities, Abt Associates developed a framework to represent the common steps grantees took to conduct project activities and to work toward target outcomes. The study team further refined the initial framework based on evaluation findings to better reflect grantee activities. The study team used this framework to help guide the analysis and presentation of evaluation findings. The chapters in this report are organized by each step in the framework: Needs and Demand, Development, Scaling, Policy Development, Institutionalization and Sustainability, and Impacts.

Each chapter is structured to show key findings, common features, and common challenges, with implications/reflections and recommendations emerging from the key findings.

Under **Needs and Demand**, we found that factors influencing research priorities included target users' needs, productivity constraints, return on investments, partner resources, and existing expertise and capabilities. Within and across grant projects, key stakeholders had differing views on who the target users of the agronomy research were. Grantees also faced challenges in designing agronomy solutions that could adapt to target users' evolving needs over time.

In **Development**, grantees found success in capacity building by expanding upon existing capabilities and agronomic systems within countries. The most transformative part of grantees' research was the inclusion of innovative research concepts and data-driven approaches to research. This use of data enabled grantees to rapidly develop location-specific agronomy

solutions. This evaluation, however, was not a scientific review and was not designed to determine the scientific validity of the grantees' approaches to development. Grantees faced challenges in budgeting and balancing enough time for all grant priorities, including conducting the research, translating research into agronomic solutions, and assessing and incorporating the need to address potential constraints. Additional challenges included capacity for digital data management. While all grant projects produced global public goods (GPGs), the number and type of GPGs produced varied by grantee, and the impact of these public goods on agronomy was unclear.

For **Scaling,** we found that involving scaling partners, both public and private, was a key part of the grantees' work, and that all grantees used similar methods to increase partners' capacity to use technologies and tools, including training of trainers workshops, demonstration trials, and collaboration with farmers' groups. For several grantees (N2Africa, ACAI, SBPEA), market system and value chain challenges affected their ability to scale their work. Grantees often started scaling activities later than originally scheduled, due to longer than planned time needed for research activities, and faced challenges in trying to scale their approaches before their grant period ended (ACAI, TAMASA, SBPEA). These challenges were particularly pertinent to the scaling of decision-support tools (DSTs). Grantees that focused on one crop (the single-phase grantees – SBPEA, TAMASA, ACAI) might have missed the opportunity to approach scaling through a more systematic lens.

For **Policy Development, Institutionalization, and Sustainability,** grantees that could build on work conducted in previous funding periods (N2Africa, CSISA, and ACAI) were better able to show achievements in policy development than other grantees that had only one funding cycle (TAMASA, SBPEA). Grantees built linkages with public and private sector partners, and engaged in building a market for their agronomy solutions to better sustain their work. Most granteess lacked a clear plan for institutionalization, and began exploring options and undertaking active measures to institutionalize only after they had reached the final stages of the funding period. Capacity building was considered an important step to facilitate institutionalization, but grantees expressed concern about the capacity of the institutes designated to adopt the agronomy solutions, particularly with respect to sustaining the data management, maintenance, and updates of data sets and technologies.

Under **Impacts,** all grant projects developed agronomic insights or innovations that led to increased yields, and most grant projects reported some adoption of agronomic innovations among farmers. During in-depth interviews, most grantees discussed their impact on the field of agronomy research in addition to or instead of their impact on target users (such as farmers). Grantees did not comprehensively measure impact, and all encountered unanticipated challenges during implementation that may have affected their ability to realize impacts.

In conclusion, we present a number of recommendations that emerged from the evaluation. These include recommendations for **better understanding and meeting existing research demand and target users' needs**, such as using demand-driven approaches to agronomy research, conducting comprehensive needs assessments as a driver for demand-driven agronomy research, integrating feedback loops from research and development (R&D), and committing to gender equality in the prioritization of research.

We also provide recommendations on how to better **innovate ways to scale agronomy solutions and increase return on research investments**. These recommendations include building linkages with a broader ecosystem of service providers, identifying and engaging with regulatory dimensions, and assessing enabling environments to scale agronomy solutions. Other recommendations include **efficiencies that could be gained by having a common platform or shared approach** among grantees, such as streamlining approaches to data collection and management and creating a platform to facilitate cross-learning. Recommendations for **increasing sustainability, efficiency, scalability and mainstreaming** of the outputs from grant projects include allowing sufficient time to scale and institutionalize agronomy solutions, identifying pathways to institutionalize and sustain agronomy solutions at the project design stage, leveraging business models and the private sector to reach scale and sustainability, clearly articulating potential sustainability pathways in project designs, and translating agronomy advisory materials into multiple local languages to encourage uptake.

Finally, we provide recommendations on **ways to improve the monitoring and evaluation (M&E) process** used by the foundation and grantees to assess progress toward targets and outcomes. These recommendations include improving M&E reporting practices, developing an improved reporting platform for M&E data, setting meaningful targets and outcomes, and shifting the approach to M&E to include demand-centric (focused on target users and target audiences) information.

1. Introduction

The Bill & Melinda Gates Foundation ("the foundation") has invested over $300 million between 2008 and 2019 in research grants under its Soil Health and Agronomy portfolio, which supports the scaling of solutions to increase productivity-led growth in the smallholder sector and spur rural sector economic development. The strategic focus of the grants has evolved to build on work achieved through previous grants.

From 2008 through 2011, the foundation made grants to develop geospatial soil-mapping, demonstrate that productivity gains are possible in a range of environments, and improve legume and cereal productivity.

From 2012 to 2015, the foundation shifted to a commodity-based value chain strategy, which continued geospatial analysis and began identifying use cases[1] based on demand, developing data-driven tools, and collaborating with scaling partners on implementation.

In 2016, the strategy evolved to include a systems focus to spur broad-based innovations and improvements in agronomy that would benefit multiple value chains, countries, and scaling partners.

As of 2020, the foundation had not completed a comprehensive assessment of its agronomy portfolio. The foundation contracted Abt Associates to conduct such an assessment. This strategic assessment included five agronomy grant projects, which are a subset of the foundation's agronomy portfolio. These agronomy grants span over a decade, cover diverse geographies in both Sub-Saharan Africa and South Asia, and work across different cropping systems:

- **Cereal Systems Initiative for South Asia (CSISA)** Phase 2 (2012-2016), and 3 (2015-2020)
- **N2Africa** Phase 1 (2009-2014) and Phase 2 (2013-2019)
- **Taking Maize Agronomy to Scale in Africa (TAMASA)** (2014-2019)
- **African Cassava Agronomy Initiative (ACAI)** (2015-2020)
- **Sustainable Banana Productivity in East Africa (SBPEA)** (2016-2020)

The foundation selected these five grants for the evaluation because they share several key characteristics that allowed an assessment of common challenges, successes, and opportunities:

- Research agendas are informed by demand-driven use case development.
- Research designs are based on sound scientific principles, with strong geospatial components in both research and implementation.
- The grantee has focused on alliances with scaling partners from the beginning.
- The grantee employs user-centric (primarily farmers and extension agents) and appropriate tool development for agricultural advisory services.

[1] *Use cases* refers to specific agronomy technologies and applications that the grants invested in, such as herbicides for cassava, early sown wheat, or inoculants for legumes.

This report presents the findings from this evaluation and is structured as follows. Given the scope of the agronomy investments, **Chapter 2** starts with a summary of the main characteristics and developments of agronomy in the portfolio, and an overview of the grants that were evaluated. It subsequently introduces a framework that provides a structure for understanding the main steps each of the grantees took in conducting agronomy research and developing agronomy solutions to create impact.

Chapter 3 describes the approach and methods used in this evaluation.

Chapters 4 through 9 are organized by the steps of the framework, with each chapter showing the key findings, common features, and common challenges. These chapters focus on conducting needs assessments and prioritizing research activities (Chapter 4), conducting transformative agronomy research (Chapter 5), approaches to scaling of agronomy solutions (Chapter 6), policy development, institutionalization, and sustainability of the agronomy research and solutions (Chapter 7), and the reported impact of each of the agronomy investments (Chapter 8). Chapter 9 concludes with providing key recommendations for future investments in agronomy.

2. Investments Reviewed

This chapter provides an introduction to the subset of the agronomy grant projects evaluated. The first section briefly describes how the grant portfolio evolved, and introduces common principles that bind these grant projects together.

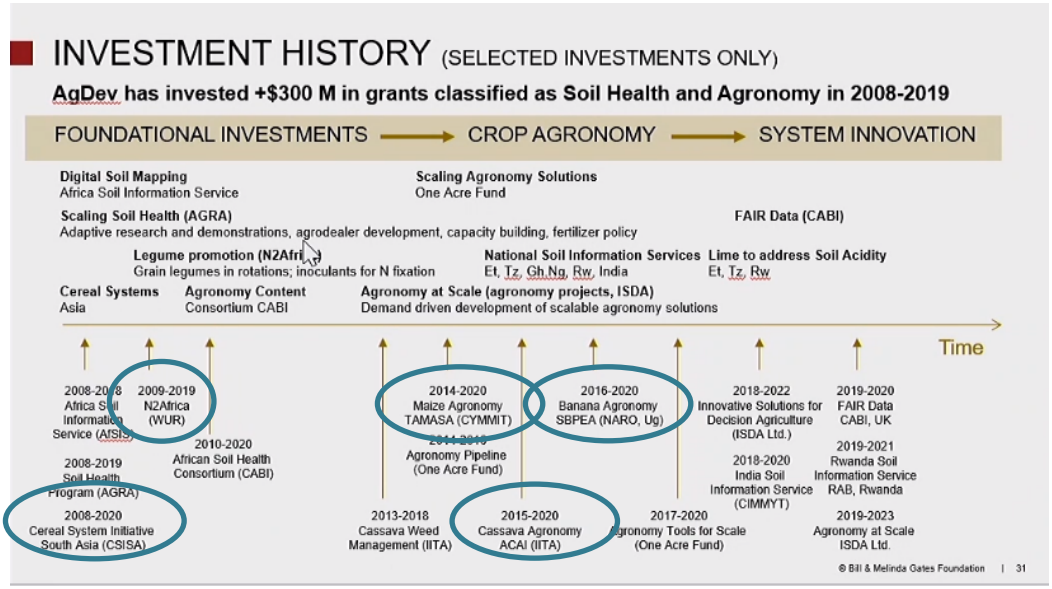
The second section briefly describes each grant project, followed by a section that presents a framework developed by Abt Associates to guide the evaluation approach based on our initial review of project activities. A more detailed description of each grant investment can be found in Appendix B.

2.1. Contextualization of the Grant Portfolio

The focus and approach of the portfolio investments evolved over the years (see figure 1).

The first years focused on foundational investments. These investments, made between 2008 and 2011, included Africa Soil Information Service, which focused on digital soil mapping and laid the foundation for the use of geospatial concepts, data, and soil diagnostics for subsequent grant projects. During this time, the foundation also began investing in the comparatively large projects, such as CSISA and N2Africa. Those grant projects consisted of multiple phases, with agronomy research focused on increasing the sustainable intensification of several cropping systems across multiple countries. CSISA in particular took a comprehensive approach to enhancing the productivity of cereal and rice systems with a growing portfolio of activities, while N2Africa aimed to increase legume productivity by working with a large number of partners in over 10 countries.

Figure 1. Foundation's Soil Health and Agronomy investment history and selected grants



Source: Presentation Kick-off Meeting Bill & Melinda Gates Foundation January 30, 2020.

Grant projects from 2012 and 2016 adopted a commodity-based approach as they focused their agronomy research on increasing the productivity of a single crop. These grant projects included grant projects funded for one funding cycle only, for approximately five years (single-phase grant projects). These included TAMASA, ACAI, and SBPEA, as well as the Cassava Weed

Management Project (which later merged with ACAI), and were characterized by a narrower scope of work, with research implemented in a limited number of countries.

These grant projects used a similar approach to agronomy R&D, by building on the geospatial concepts and soil maps of the African Soil Information Service; and adopted demand-driven prioritization of research that involved a range of stakeholders, and field-research using geospatial sampling frames. They developed digitally enabled innovations that provide farmers with decision support frameworks.

While these grant projects have different time spans, and vary in the scope of work and geographical focus, the grant projects have a number of principles in common.

First, the research agenda is increasingly informed by demand-driven use cases.[2] To ensure relevance of use cases, grantees involve stakeholders and target users (beneficiaries) in use case prioritization and development. Stakeholder and target user participation reflects the shift from supply- to demand-driven approaches in the field of agronomy. The challenge of generating large-scale adoption in agricultural systems has over time put more and more emphasis on the importance of a research design that ensures relevance to the needs of smallholder farmers. This in turn has increased the analysis and understanding of target users and of their participation in the research design process (Lynam and Twomlow, 2014).

Second, the demand-driven approach also informs user-appropriate agronomy solutions (recommendations, tools, and technologies developed from the agronomy research conducted). This approach allows projects to develop and deliver tools and technologies based on inputs of stakeholders and target-users, and aims to ensure that solutions are appropriate for use by these beneficiaries.

Third, research designs of agronomy grant projects are based on scientific principles, with geospatial components in both research and implementation that address the diversity of agricultural systems and regional locations. This approach requires grant projects to use a range of scientific methods to gather crop response data, such as multi-locational field trials, laboratory experiments, and/or demonstration trials. Geospatial soil data is used to understand crop contexts and to develop site-specific recommendations. This reflects the shift away from delivering general recommendations to instead developing agronomy recommendations that recognize location differences and the importance of the context of crop production (Buerkert et al., 2001, VanLauwe et al., 2016).

Lastly, there is a focus on alliances with dissemination or scaling partners – those partners that help disseminate agronomy solutions to beneficiaries. To create widespread impact, the scaling of agronomy solutions is integral to these investments. Establishment of effective partnerships with public and private sector organizations and their alignment of skills, capacity and resources aims to increase the development and relevance of agronomy research and solutions (Pingali, 2012).

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[2] *Use cases* refers to specific agronomy technologies and applications that the grant projects invested in, such as herbicides for cassava, early sown wheat, or inoculants for legumes. Demand-driven research focuses on the needs and demands of key stakeholders and target users or beneficiaries.

2.2. Brief Description of Grants

As mentioned earlier, grant projects are described in greater detail in Appendix B.

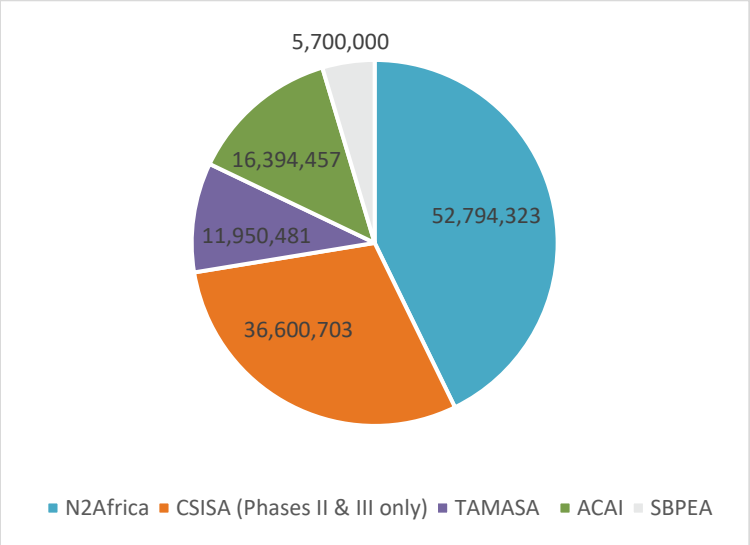
N2Africa (September 2009–June 2019, *$52 million*) was implemented by Wageningen University. It sought to enhance legume production in sub-Saharan Africa through improved legume varieties and biological nitrogen-fixation technologies, including fertilizer and rhizobium inoculants. The project spanned two phases and operated in 11 countries.

Cereal Systems Initiative for South Asia (CSISA) (November 2008 – February 2021, *$59 million*) seeks to address yield constraints across three cereal systems – rice, maize, and wheat – in three countries: Bangladesh, Nepal, and India (Bihar, Odisha, and Eastern Uttar Pradesh). CSISA takes a multi-faceted approach to address a multitude of agronomic constraints across these cereal systems, and has worked with a range of public and private sector partners to build their capacity and reach scale. The grant has been implemented through three phases. *This review focuses on Phases II and III only*, as they are more recent and data was most available for these phases.

Sustainable Banana Productivity in East Africa (SBPEA) (September 2016-July 2020, *$5.7 million*) was led by the National Agricultural Research Organization to improve productivity and sustainability of banana-based systems in Uganda and Tanzania.

Taking Maize Agronomy to Scale in Africa (TAMASA) (November 2014–December 2019, *$11.9 million*), implemented by the International Maize and Wheat Improvement Center (CIMMYT), aimed to improve the attainable yield gaps in maize production and improve the productivity of small-scale maize farmers in Ethiopia, Nigeria, and Tanzania.

Figure 2. Funding amounts by grant project



African Cassava Agronomy Initiative (ACAI) (September 2015–December 2020, *$16.4 million*), implemented by the International Institute of Tropical Agriculture, aimed to improve cassava root yields and quality, and strengthen cassava supply chains in Nigeria and Tanzania.

2.3. Framework

After a preliminary review of project activities, Abt Associates developed a framework to represent the common steps taken by grantees to conduct project activities and to work toward target outcomes. The study team further refined the initial framework, based on evaluation findings, to better reflect grantee activities (see final framework in Figure 3). The study team also used this framework to help guide the analysis and presentation of evaluation findings. Hence, the subsequent chapters of this report, which present the evaluation findings, are structured according to this framework.

As **needs and demand** underpinned most investments in agronomy, the framework begins with an assessment of needs and demand for the research and technologies considered for development and dissemination.

Informed by the needs assessment, the framework then focuses on **transformative agronomy research**, including data collection and the translation of data into actionable R&D. Agronomy research is translated into actionable insights for the use cases, which form the basis for the **development of tailored agronomy solutions**. These agronomy solutions include improved agronomic practices, advisory tools to support farmer decision-making (e.g., DSTs), and agronomic technologies (e.g., fertilizer blends, inoculants). Similarly, agronomic research provides inputs for the creation of **global public goods (GPGs),**[3] including data and knowledge exchange platforms to enable scaling and the development of soil and information services such as geospatial soil maps.

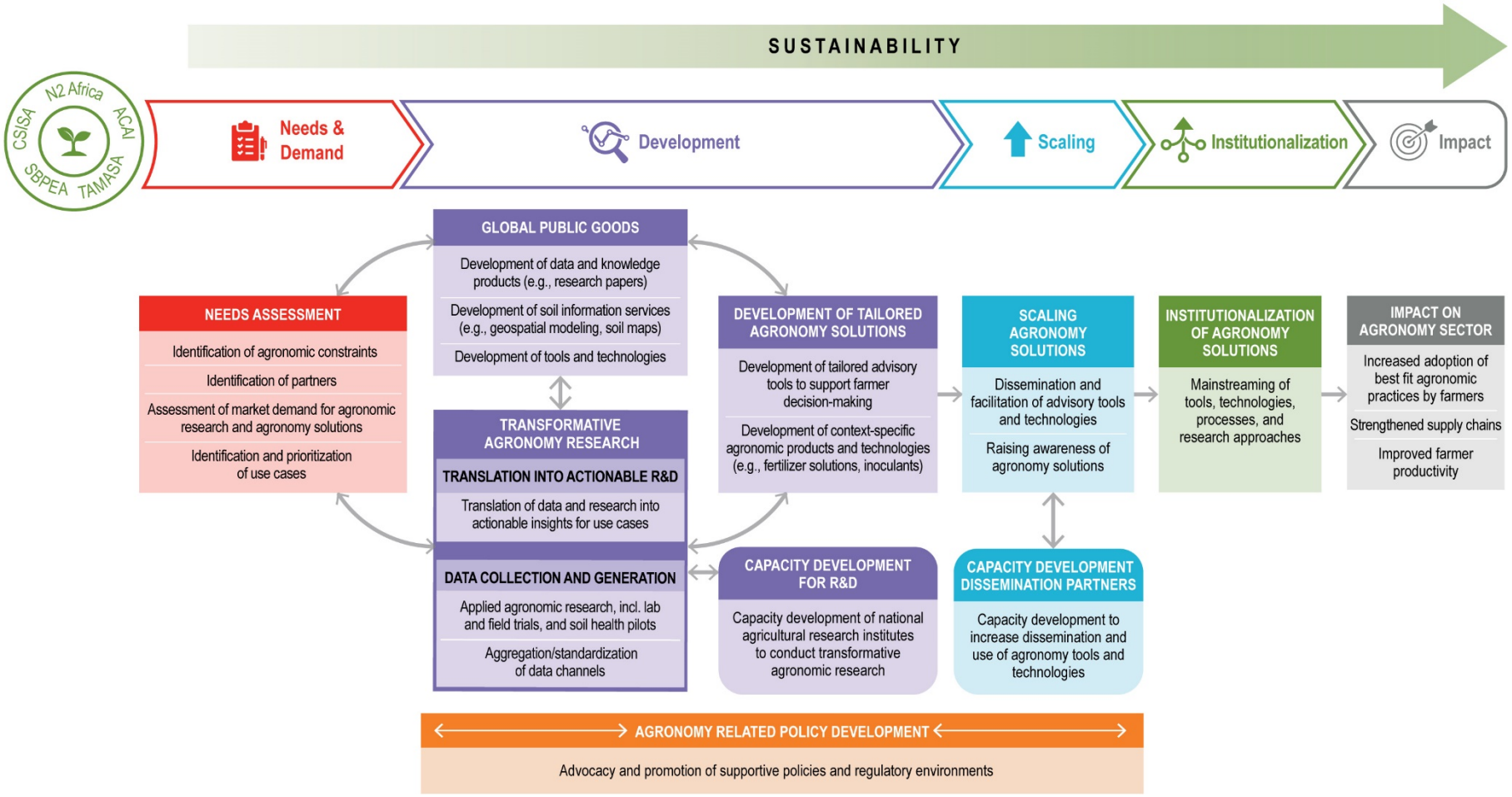
Grant projects also invested in **capacity development** of researchers and engaged them in the agronomy R&D, including field trials.

Grantees focused on **scaling** of research products and technologies by working with public and private sector partners and with nongovernmental organizations (NGOs). The technologies and products are disseminated through the partner-led dissemination networks to farmers to enhance farming efficiency and productivity. In support of dissemination or scaling, grantees also conducted **capacity development of dissemination partners** such as extension workers who use and support the distribution of the tools and technologies and assess and respond to farmer needs.

Agronomy research and solutions are also **institutionalized** in key international and national research organizations, and integrated in other bodies of research to continue the work of the grantees. Some grantees engaged in **agronomy-related policy development** and policy change in an effort to create an enabling environment with supportive policies and regulations aligning with value chain partner interests. Finally, through each of these activities, grantees aimed to improve the **sustainability** of both the agronomy research and the delivery of agronomy solutions into farmers' fields. All the work of the grantees was an attempt to lead to **impact on the agronomy sector** in the countries where grantees worked, via increased adoption of best fit agronomic practices by farmers, strengthened supply chains, and improved farmer productivity.

[3] Global public goods are loosely defined here as goods whose benefits reach across borders, generations and population groups and include, as another subgroup, regional public goods. These are publicly available recommendations, tools, technologies, and data whose benefits reach across borders, generations and population groups. This would include research products, computer code, data, and decision support tools, all made publicly available. Global Policy Forum, www.globalpolicy.org/component/content/article/215-global-public-goods/46038.html, (accessed March 26, 2020).

Figure 3. Agronomy Grants Framework



3. Approach

This chapter describes the approach for evaluating the five agronomy grant projects, and includes a basic overview of the evaluation themes and key research questions (RQs) and data sources.

3.1. Themes and Key Research Questions

Three key themes and a series of RQs under each theme guided the evaluation. Each were developed by the foundation for the original evaluation proposal and modified slightly by Abt in conjunction with the foundation. Table 1, Table 2, and Table 3 list the original themes, RQs and data sources used to answer each RQ.

Table 1. Theme 1 evaluation questions

Theme 1: Achievements, outcomes, and shortfalls of individual grants									
Main questions	Desk review			Interviews		M&E data	Online survey	GIS/ remote sensing in Bihar	Household survey in Bihar
	Project reports and materials	Country documents	Peer-reviewed articles	BMGF staff	Stakeholders	Report and data review	BMGF staff and stakeholders	Landsat and Sentinel	Smallholder wheat farmers
1. What were the achievements of each of the grants?	◆	◆		◆	◆	◆	◆		
2. What was the impact of the grant on the sector of agronomy at the country level?	◆	◆	◆		◆	◆			
3. How have the GPGs created under these grants been applied or made impact at country level?	◆				◆		◆		
4. To what extent did grants achieve their target outcomes? What were the factors that contributed to meeting or falling short of target outcomes?	◆			◆	◆	◆	◆		
5. What are the evaluation firm's recommendations to better innovate the way we do agronomy at scale and increase the return on the R&D investments?	◆	◆	◆	◆	◆	◆			
6. What was the impact of CSISA's early sown wheat project on adoption, yield and farmer income?								◆	◆

Table 2. Theme 2 evaluation questions

Theme 2: Examining the model for assessing and meeting demand							
Main questions	Desk review			Interviews		M&E data	Online survey
	Grant reports and materials	Country documents	Peer-reviewed articles	BMGF staff	Stake-holders	Report and data review	Grantee staff and stakeholders
7. How was research prioritized and what factors influenced prioritization? Who were the identified target users of research and were their needs met?				◆	◆		◆
8. What have been the main lessons in terms of the various approaches to understanding and meeting existing research demand and end users' needs?				◆	◆		◆
9. What are the recommendations for better understanding and meeting existing research demand and end users' needs moving forward in agronomy research and implementation?				◆	◆		◆

Table 3. Theme 3 evaluation questions

Theme 3: Common challenges, barriers, and outputs across the grants							
Main questions	Desk review			Interviews		M&E data	Online survey
	Grant reports and materials	Country documents	Peer-reviewed articles	BMGF staff	Stake-holders	Report and data review	Grantee staff and stakeholders
10. What challenges or barriers to success exist across the grants?				◆	◆	◆	◆
11. Have there been similar outputs or systems developed across the grants? If so, could efficiencies have been gained by having a common platform or shared approach?				◆	◆		
12. What recommendations does the evaluation firm have for increasing sustainability, efficiency, and scaling, and mainstreaming the outputs from the grants?				◆	◆	◆	
13. Which outputs/approaches are most relevant for a more systematic approach?				◆	◆	◆	
14. Which efficiencies could have been gained by having a common platform or shared approach?				◆	◆	◆	

This report addresses the RQs under each theme. While we were able to address RQs under Themes 2 and 3, the study team was unable to fully address several study RQs under Theme 1, because of a lack of available data, and data collection obstacles resulting from COVID-19.

From **Theme 1:**

- For RQ2, *impact of the grant on the agronomy sector at the country leve*l, there was limited data across grant projects on these types of impacts, particularly at the country level, and much of the data to answer the question focused on contributions to the agronomy sector instead of impacts. Therefore we report both impacts and contributions, as we were unable to consistently answer this question for each grant project.
- For RQ3, *GPGs, while we were able to determine GPGs produced by grantees*, data on the impacts of these GPGs was also very limited, so we report the application of GPGs and not country level impacts.
- For RQ4, *target outcomes*, grant projects also had limited and inconsistent reported data. Targets were sometimes listed initially but not reported later, or were not listed at all. Grantees also set their own target outcomes, and no standardized set of outcomes existed across grant projects. When possible, we report the extent to which the grantee met target outcomes.
- For RQ6, *CSISA impacts of early sown wheat,* we were unable to conduct the Household Survey due to domestic and international health and travel limitations from COVID-19. We did conduct the GIS/remote sensing analysis (see Appendix C for key findings and Appendix D for additional graphs from the analysis), but there were limitations in the available data, and findings were inconclusive.

3.2. Data Collection and Data Sources

The study used four main data collection methods for the evaluation, all focused on the five grant projects. Methods included a *desk review*, a *review of monitoring and evaluation (M&E) data, key informant interviews,* and an *online survey* (see Table 4). More details on each of these methods are found in Appendix A.

The *desk or document review* was an assessment of primarily program-level documents provided by the foundation, supplemented with key grantee evaluation reports when available, to gather information on the design, implementation, outcomes, and country context of each grant project. The team synthesized documents using a template (see Appendix F) to assess common themes, allowing for comparison across grant projects.

For the *review of M&E data*, the team examined grantee results frameworks for each reporting period, and indicator performance during the grant periods. We used the M&E data from the results frameworks and indicators to assess the grantees' achievements against their targets.

We employed *key informant interviews* across grant projects to elicit thoughts and opinions from foundation staff and agronomy experts, and also conducted interviews with key grantee staff and partners for each grant project.

Finally, the study team designed and fielded a short *online survey* to capture stakeholder experiences with each grant and provide more-standardized cross-grant perspectives. Online survey respondents did not include key informant interviewees, but did include individuals who had worked with partner or stakeholder organizations during grant implementation.

To integrate and triangulate results from the desk review, M&E data review, key informant interviews, and the online survey, the team used a triangulation framework. Data triangulation allowed us to examine where the various structured and semi-structured data sources agreed and disagreed and to explore apparent discrepancies.

Findings presented in this report draw from all relevant data sources and the report notes when findings are limited to fewer sources.

Table 4. Data sources by grant

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Cross-cutting	Total
Interviews							
Grantee	10	7	3	7	7		**34**
Stakeholders and partners	9	15	9	10	6		**49**
BMGF staff						3	**3**
Agronomy experts						6	**6**
Total	**19**	**22**	**12**	**17**	**13**	**9**	**92**
Online Survey							
Survey respondents	34	21	21	21	17		**114**

4. Needs and Demand

A key focus of the work of the grant projects in this portfolio was **demand-driven research**. This type of research focuses on the **needs** and **demands** of key stakeholders and **target users**. In agronomy research, **target users** can include government institutions, research partners, private sector partners, agro dealers, scaling partners, extension agents and farmers, who all gain from using the data, products, technologies or tools that the research generates.

In agronomy, **needs assessments** can help grant projects develop research agendas that are more **demand-driven,** with stakeholders, including farmers, taking a more prominent role in deciding priorities and planning agronomy research. **Needs assessments** can be used to maximize understanding of how to address key agronomy constraints and the diversity of local agro-ecological zones, whether agronomic solutions can be sustainably and cost-effectively scaled, and whether viable delivery pathways exist.

As part of its funding requirements, the foundation instructed grantees to **prioritize demand-driven research** by developing and prioritizing **use cases** (key research activities to understand how a specific existing/emergent technology would be applied in a new context, or to demonstrate viability of a specific technology that would be the major focus of the grantee's work). Detailed **use cases** also described how grant projects envisioned that research and solutions would be applied.

KEY FINDINGS

- Grantees took a **demand-driven approach** to define their activities, conducting literature reviews, consulting stakeholders to prioritize research, and **seeking feedback from partners and target users** to help ensure that the potential research and solutions developed would meet their needs.
- A **number of factors influenced the prioritization of research**, including target users' needs, productivity constraints, return on investments, potential for scale, partner resources, and existing expertise and capabilities.
- Within grant projects, key stakeholders had **differing views on who the target users** were of the agronomy research.
- Grantees faced **challenges in designing agronomy solutions** that could adapt to target users' evolving needs over time.

This chapter includes a discussion across grant projects on the **needs and demand** activities that were part of the grantees' work. We present the discussion by common features across grant projects, challenges, and then key conclusions. Examples of innovations, unique contributions and promising practices by individual grantees related to needs and demand are highlighted in text boxes in the common features section. Findings are synthesized across data sources and include data from the document review, interviews, online survey and M&E data. More detail on the work of each grantee related to **needs and demand** is provided in Appendix B.

4.1. Common Features Across Grant Projects

Grantees took a demand-driven approach to define their activities, conducting literature reviews, consulting stakeholders to prioritize research, and seeking feedback from partners and target users to help ensure that the potential research and solutions developed would meet their needs.

While foundational grant projects (N2Africa, CSISA) initially defined their scope and research priorities primarily in consultation with agronomic experts, subsequent grant projects (SBPEA, ACAI, TAMASA) increasingly took a more demand-driven approach based on consultations with a larger range of stakeholders and beneficiaries.

A key component in assessing need and demand was the literature reviews conducted during the proposal process, and these literature reviews served as the first step in the needs assessment stage by providing information on successes, challenges and gaps in research.

ACAI: Literature Review

ACAI conducted a literature review to identify key constraints in the cassava value chain and find knowledge gaps related to increasing cassava yields.

Alongside the literature review, ACAI collected current knowledge on agronomic interventions in cassava-based systems, studied the applicability of methodologies for fast and cost-effective plant sampling techniques to assess nutrient constraints, and reviewed advances in crop growth modelling for cassava in other initiatives. This improved understanding of the limitations in cassava systems and helped avoid duplication of efforts while focusing resources on the most critical knowledge gaps. By December 2019, ACAI reported that they had reviewed 203 studies with data relevant to the use cases, with, in total, 4,796 observations across 29 countries.

The extent to which foundational grant projects undertook literature reviews during their first phase is not clear, but subsequent phases and the later funded single-phase grant projects used extensive literature reviews to define the scope of work and steer the direction of their research.

SPBEA: Detailed Needs Assessment

SBPEA initially proposed seven use cases in the proposal that focused broadly on integrated soil fertility and pest management. The team identified the use cases based on 20 years of in-country banana research as well as conducting a search of relevant literature, undertaking a baseline survey, and analyzing where there were gaps in agronomic research and technologies. After grant approval, the grantee conducted initial workshops at each action site, in which stakeholders ranked constraints and prioritized use cases.

SBPEA was also able to include needs of farmers in use cases and the research prioritization process. Initial meetings with farmers grouped them into different categories – A, B, C, D – based on income, region, resources, size of landholding, and current use of recommended agronomic practices. Agronomic practices were then targeted to the specific needs of each farmer "group." While the goal was to have comprehensive soil, water and pest management practices implemented, the goal was to have farmers start implementing different practices depending on their "grouping." Farmers were often identified by grantee respondents as the target user for the research.

TAMASA, SBPEA and ACAI involved a range of partners to further co-develop the scope of their research. Interview respondents from SBPEA and ACAI emphasized the importance of engaging partners early to allow for a co-creation process where stakeholders helped shape the research agenda ensuring that use cases were prioritized based on their perception of key constraints. SBPEA extensively involved farmers of all sizes and income levels in their prioritization of research, which allowed them to get a clearer picture of farmers' demand for different agronomy solutions and therefore the research supporting the solutions.

Most grantees recognized gender differences in agricultural productivity and indicated in grant proposals that they would address these differences. N2Africa, in particular, aimed to empower women by focusing on production of nutritionally improved legumes and labor-saving technologies. However, while grantees increasingly involved stakeholders in identifying key constraints to crop and farmer productivity, grantees did not explicitly identify constraints to gender outcomes in needs assessments.

Implications/Reflections:

Later grant projects, particularly ACAI and SBPEA, appeared to have a thorough, comprehensive approach to conducting needs assessments that involved multiple stakeholders and target users, which may have been connected to the way the foundation was framing and awarding the grant projects, although this was not clear from reviewing grantee documents or from interviews.

Recommendations:

The foundation should require grantees to share the literature and the analysis of gaps, successes and challenges from their literature reviews. These literature reviews could be housed in a central location or repository, allowing other and future grant projects to easily access these reviews when developing their own demand-driven research, and enabling them to easily build upon the earlier research for similar crops, countries, tools, etc.

The foundation should consider developing a standardized approach to needs assessments: helping grant projects identify the types of key partners that should be involved; and building upon the best practices for needs assessments developed by ACAI and SBPEA as models to ensure that research is demand-driven and reflects the needs of key stakeholders and target users.

To better intentionally address gender, the foundation may need to have a more systematic approach to identify gender dimensions that can be addressed through proposed agronomy research and provide guidance to grantees on how to do so. The specific identification of challenges women face and how agronomy solutions could contribute to improving gender outcomes in agriculture should be integrated into needs assessments.

A number of factors influenced the prioritization of research, including target users' needs, productivity constraints, return on investments, potential for scaling, partner resources, and existing expertise and capabilities.

Most interview and survey respondents[4] said that the needs of target users (specifically with regard to productivity constraints), are important to consider in the first steps of defining a scope of demand-driven research. Grantees proposed research that aligned with their own expertise and experience, and they also assessed partners' capabilities and resources to conduct the research. As grant projects built on the expertise of in-country research institutes and systems, they relied on in-country researchers to participate in the research, and grantees often required partnering research institutes to make a budget available to contribute to the research.

[4] In the online survey we asked respondents to rank the factors that they perceived were most important in prioritizing research. The results are presented in Appendix E.

There is insufficient evidence on the degree to which most grantees considered factors related to returns on investments for farmers, which included the affordability and profitability of technologies, the potential to impact crop yield and farmer productivity, and the scalability of agronomy solutions. There was also insufficient evidence as to whether or not grantees considered country "readiness" for digital agronomy solutions, whether farmers and extension agents had familiarity with digital solutions, and whether supportive within-country structures, such as cellular networks, would allow these solutions to be accessible for the target users. The foundation might not have required such considerations as part of the research prioritizing process.

CSISA Phase II – Ex Ante Analysis

Lessons learned from Phase II-informed Phase III programming:

During the last stage of Phase II, CSISA conducted an ex ante analysis to pause and reflect on their research portfolio and reprioritize use cases. The analysis aimed to identify use cases with a high impact potential and a good return on investment. A priority index was used to prioritize interventions based on factors such as potential yield gains, number of farmers that could benefit, scalability, and profitability. The analysis also considered the degree to which the market already addresses the problems, the extent to which progress would hinge on CSISA activities, and the feasibility and intensity of the proposed activities.

ACAI: Early Involvement of Partners

ACAI involved potential dissemination partners very early (before and during the proposal stage). The project contacted potential dissemination partners concerning agronomic constraints in cassava productivity, supply, and/or quality, and their needs to fill these gaps. ACAI developed needs assessments among agricultural input manufacturers, distributors, cassava buyers, and processors and selected partners based on their existing dissemination networks in cassava producing areas. Each were engaged in shaping the research agenda, defining the purpose of various decision support tools, and determining the format and packaging of outputs.

The potential to scale was another factor that some grant projects included in prioritizing research and agronomy solutions. As grant projects invested extensively in agronomy research, the return on investment depended on the scalability of technologies. Interview respondents and grant project documentation provided very limited evidence that potential business models and go-to-market strategies for technologies were considered during the needs assessment period (only N2Africa did this), but such models could provide a pathway to commercialization for agronomy solutions. Neither was there evidence from any data source that grantees conducted early assessments of potential risks stemming from the policy or regulatory environment. (These are policies and regulations that might hamper the work of grant projects in certain countries – such as value added taxes on crops, which decrease demand (N2Africa), and limitations on fertilizer imports (ACAI, TAMASA)).

While grantees increasingly involved stakeholders in identifying key constraints to crop and farmer productivity, grantees did not explicitly identify constraints to gender outcomes during needs assessments. Most grantees recognized gender differences in agricultural productivity and indicated in their grant proposals that they would address these by involving women in trainings and by improving the adaptation and uptake of agronomy solutions for women. N2Africa, in particular, aimed to empower women by focusing on production of nutritionally improved legumes and labor-saving technologies.

Implications/Reflections:

The lack of data on the degree to which grantees considered factors such as scaling, in-country resources, and returns on investment is notable. Later phases of multi-phase foundational grant projects and two of the single-phase grant projects appeared to consider more of these factors, and the foundation may have been driving these considerations.

Policy and regulatory environments are important to consider when determining which external factors may facilitate or obstruct grant project activities, and these may be different for each country where the grant project is working. Grant projects need to adjust their work based on assessments of these environments. Considering business cases or models and how they can provide a means to commercialization is particularly important when grant projects are working towards solutions or products (particularly DSTs) where the expectation is that private sector companies will assume the work (TAMASA, ACAI, SBPEA).

While grant projects had a real focus on digital technologies, target users' (farmers and extension agents') lack of familiarity with digital approaches raises questions as to whether these approaches truly emerged from demand-driven research. It also raises questions as to whether targeted countries were ready for these approaches, and how grantees could better assess country "readiness" for digital approaches. With limited considerations of need or readiness, grantees were at risk of developing applications that were facing substantial barriers to sustainability from the outset.

Recommendations:

Any comprehensive needs assessment should include a feasibility or constraints analysis. This would be an assessment of the variety of factors that influence the later aspects of the work of the grant project – dissemination and scaling – in particular, the policy and regulatory environments and potential paths to commercialization. While grantees might not have the skills to do this work, the foundation should provide guidance on how to conduct these needs assessments, and the types of questions that should be included in the assessments. The foundation should provide clear feedback to grantees on theories of change and logic models developed for grant activities, as a way to ensure these factors are adequately included in needs assessments. This would be a tool for the foundation to identify gaps in logic or untested assumptions that could be supported through additional grants or other targeted support.

Grantees should provide results from needs assessments to the foundation, so that the foundation has a good understanding of the factors that are influencing the work of the grantees and has a better sense of how it can support the grantees.

Finally, grant projects need better guidance and/or ways to measure country readiness for digital solutions. They need guidance on when to move forward with planned digital research or when to shift funding to other countries that demonstrate better readiness. The foundation could allow flexibility in funding and encourage grantees to determine what needs to be done to create markets and demand for digital technologies, in countries that are only in the early stages of readiness.

4.2. Common Challenges

Grantees and stakeholders identified a number of challenges related to prioritizing research and use cases through needs assessments with partners.

Within grant projects, key stakeholders had differing views on who the target users were of the agronomy research.

The majority of interview respondents identified farmers, particularly smallholder farmers, as the target users of the agronomy research. These respondents felt that agronomy recommendations and technologies were ultimately meant to improve farmer productivity and income.

Interview and survey respondents and grant project documents also identified scaling partners and extension agents as target users, as they play a key role in providing agronomy recommendations and technologies to farmers, especially in the use of DSTs. Fewer respondents referred to research scientists as target users.

The type of agronomy solutions some grantees were planning, particularly those grantees focused on developing DSTs, required grant projects to make a more explicit distinction of target users. DSTs could take on very different formats, from paper-based forms to digital apps on smartphones. ACAI developed six different DSTs in different formats (paper or digital) based on an assessment of target users' needs.

ACAI: Decision Support Tools

Fertilizer site-specific recommendation decision support tool: This tool provides specific fertilizer recommendations, based on queries related to soil fertility conditions, past management practices, desired yield increases, fertilizer availability and prices, and variety used, amongst other.

Best planting practice decision support tool: This tool provides site-specific information on appropriate land preparation, including aspects of weed management, tillage, and ridging based on topsoil properties, plant populations, cassava planting material length and quality, appropriate angle of planting and other desired information.

Cassava intercropping decision support tool: The intercropping tool provides information on appropriate populations, spacing, and relative planting times of cassava.

Staggered planting decision support tool: The staggered planting tool was developed to counter the over-supply of fresh roots during peak periods and low or lack of supply during large periods of the year. The tool provides recommendations based on current yield, price expectations during the harvest window, and market type (processor paying according to starch content or common fresh root market).

High starch content decision support tool: The tool advises on appropriate agronomy and harvesting times for maximizing the starch content of fresh cassava roots, which includes recommendations on variety, time of harvesting, and growth conditions affecting the starch content of cassava roots.

Six Steps to Cassava Weed Management tool. Recommendations on integrated weed control, developed under the CWMP.

Several grantees (ACAI, TAMASA and CSISA) realized during project implementation that DSTs, especially those used on smartphones, were most likely too complex for farmers to use directly, and changed the target users for the DSTs. Not all partners were aware of changes in target users.

Implications/Reflections:

There was a lack of consistency in defining target users within grant projects, which is important to note, because agronomy solutions generally are developed to meet the needs of the target users. If the solutions are not meeting the needs of the target users, they will have greater difficulty extending to the ultimate beneficiaries. For example, if the target user is defined as extension agents and the needs of the extension agent are not met (solution is easy to use, understand and explain; requires minimal resource use by extension agents; is of interest to and demanded by farmers), then the ability to extend the solution to the ultimate beneficiary (farmers) will be much more limited.

Some partners were unaware of changes in target users, which might have made the original approach to research activities less useful.

Recommendations:

The foundation should consider defining agreement on target users as a stage of the needs assessments or co-creation of research agendas. This can better shape the work of the grantees and help determine consistency in approaches across grant projects. Such standardization is particularly important when grant projects are working on similar approaches, to ensure that they are developing research and solutions that are applicable to similar target users.

In addition to reviewing, and providing guidance on, grantee definitions of target users, the foundation should discuss with grantees how they are defining target users and what this means for each grantee based on the types of research and potential solutions prioritized. For example, if the goal is to have target users such as extension agents implement DSTs, how is the approach different than if farmers are the target users? What features of DSTs do extension agents feel are most helpful? What kinds of information do farmers find most useful and what are they actually able to implement?

Grantees faced challenges in designing agronomy solutions that could adapt to target users' evolving needs over time.

Most grantees emphasized the importance of involving stakeholders in agronomy research but found the co-creation of use cases, as part of the needs assessments, to be time intensive. Through grantee documents and interviews, some grantees reported that they extensively consulted experts, stakeholders, and potential partners prior to the development of the proposal. N2Africa, for example, went through a "lengthy consultation process" through conferences and workshops with experts and the foundation to develop and get an endorsement for their research agenda. SBPEA reported that the establishment of field trials was delayed partly as a result of consulting scaling partners and obtaining their input for prioritizing DSTs.

Grant projects often involved National Agricultural Research System (NARS)/research partners in needs assessments and prioritizing research, assuming they would be able to free up the resources and meet their cost-sharing commitments. During implementation, however, demands on the research agenda and research partners can also shift, which creates the risk that partners are not able to meet their commitments. One agronomy expert familiar with CSISA's work reported that the grant project's scope of research expanded during implementation as a result of additional demands from partners and donors which made the grant project more complex to manage. CSISA's ex-ante analysis during Phase II reprioritized the grant project's activities, removing some of the components that had been added earlier. ACAI indicated that initial cost-

sharing arrangements were not always realistic, especially when field research became more intensive.

Implications/Reflections:

While grant projects attempted to assess in-country resources and time constraints, they may have made assumptions about resources and capabilities that were not entirely accurate or they may not have been effectively leveraging consultations with partners to their benefit, which led to later delays in conducting research.

Considering these challenges can help grant projects better prioritize research and help set realistic targets and outcomes that can achieved during the funding period.

Recommendations:

Both grant projects and the foundation should consider the time needed to co-create a research agenda and both time and funding should be built into grant projects to allow for the creation of research agendas. Along with guidance from the foundation on how best to do so, funding a variety of partners may also allow grant projects to better assess partner resources and facilities for conducting planned research.

5. Development

The next step in the framework is the **development** step. This part of the framework focuses on **capacity development for research and development (R&D)**, **transformative agronomic research,** the development of **tailored agronomy solutions**, and **GPGs**.

Capacity development for R&D is building the capacity for conducting agronomic research within a country. It can include supporting graduate students to be trained in agronomy research at the university level; or can be training and improving the capacity of research institutes, researchers, and other key partners to conduct agronomic research, collect data (including digital data collection methods), and develop and manage agronomic databases. **Transformative agronomic research** is research that has the potential to make a major change or transformation in agronomic practices; it includes new and innovative research ideas that could have high potential impact in the field of agronomy. It includes applied agronomic research, such as lab and field trials, soil health pilots, aggregation/standardization of data channels, and data collection and generation.[5] **Tailored agronomy solutions** include recommendations or approaches to address certain agronomic conditions or identified programs. These solutions are tailored to specific countries, regions, crops, varieties, and soils, and include a range of agronomic practice recommendations.

GPGs are publicly available recommendations, tools, technologies, and data whose benefits reach across borders, generations and population groups. They form part of the broader group national public goods, which include **regional public goods** as another sub-group. This would include research products, computer code, data, and decision support tools, all made publicly available.[6]

The components included in **development** work synergistically together; they were also the main focus of the work of the grantees. **Transformative agronomic research** often informs **tailored agronomy solutions,** and **capacity development** allows in-country researchers, research institutes and key partners to develop new research skills or build upon existing research skills, and participate in transformative agronomic research and in developing tailored agronomy solutions. **Development** also includes the production of **GPGs** where research and agronomic solutions are often bundled together and made publicly available for use within country and globally.

This chapter includes a discussion across grant projects on the **development** activities that were part of the grantees' work. We present the discussion by common features across grant projects, followed by challenges, and then by key conclusions/recommendations. Examples of innovations, unique contributions and promising practices by individual grant projects related to development are highlighted in text boxes in the common features section. Findings are synthesized across data sources and include data from the document review, interviews, online survey and M&E data. More detail on the work of each grantee related to **development** is provided in Appendix B.

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[5] This evaluation was not a scientific review and therefore was not designed to determine the scientific validity of the approaches to research and development used by grantees.

[6] Abt worked with the foundation to create a definition for **global public goods** to use when assessing the work of the grantees.

KEY FINDINGS

- Grantees found success in **capacity building by expanding upon existing capabilities** and agronomic systems within countries.
- The **most transformative part of grantees'** research was **the inclusion of data-driven approaches** in research. Incorporating the data-driven piece into research had the potential to rapidly develop location-specific agronomy solutions.
- Grantees faced **challenges on budgeting/balancing enough time** for all grant priorities, including conducting the research, translating research into agronomic solutions, assessing and incorporating the need to address potential constraints. **Additional challenges included capacity for digital data management**.
- While all grants produced global public goods (GPGs), **the number and type of GPGs produced varied by grantee**, and the **impact of these public goods** on the agronomy sector was unclear.

5.1. Common Features Across Grant Projects

Grantees found success in capacity building by expanding upon existing capabilities and agronomic systems within countries.

While the foundation did not explicitly design the agronomy grant projects for the purpose of capacity building, it was nevertheless a key component of the work of all of the grantees. Most grant projects strategically developed or attempted to build upon existing in-country research capabilities when prioritizing research. In addition to assessing demand, when deciding which transformative research strategies could be most feasible, they considered already existing in-country systems or research capacities related to the focus of the grant project. Interview respondents and grantee documents both described this thinking.

N2Africa: Large Numbers of Scientists Trained

N2Africa achieved success in both Phases I and II in capacity building; it built upon existing skills in rhizobiology research within project countries. In Phase I, the project sponsored 17 MSc and six PhD students and involved "140 scientists, technicians, farm liaison specialists, and others in nine countries, 30 percent of whom are women" in rhizobiology activities and trainings. Phase II supported 79 MSc/MPhil students (35 percent female) and 24 PhD students (42 percent female).

Building upon research capacity allowed grantees to leverage in-country expertise. This process was particularly true for SBPEA, whose grant project was housed with NARO, a leading institute in banana research in Uganda, and for N2Africa related to rhizobiology researchers. It was also true for CSISA in developing the capacity of the existing agricultural extension system (Krishi Vigyan Kendra (KVK)) agents to conduct digital research.

Another key piece of capacity building in agronomic research can be the funding of graduate students. The foundation strategically includes graduate student topics in its grant funding and most[7] (N2Africa, TAMASA, ACAI, SBPEA) grant projects supported graduate students from the countries of focus. In addition, many of the foundation's investments have a regional focus, which allowed students to connect with regional and international scientists.

[7] CSISA trained students in Phase I, which was not included in this assessment.

As researchers, grantees felt these (number of scientists, researchers, and graduate students trained) were important, and easily measurable metrics to include in their reporting. However, grantees did not describe the longer-term outcomes of capacity building.

CSISA: Training Extension Officers on Digital Research

By the end of Phase II, CSISA had secured an agreement with the Indian Council of Agricultural Research to train Krishi Vigyan Kendras (KVK, an agricultural extension system) officers to conduct field-research for the Landscape Diagnostic Survey (LDS), which was used to inform many partners about farmer practices in the field. In Phase III, CSISA published key findings from the LDS and each KVK officer used data they collected to write a chapter in the publication on their region, both increasing KVK data collection skills and allowing KVK partners to have public recognition for their expertise and work.

Implications/Reflections

National and international connections made by scientists, researchers, and students may add value to training, help to advance knowledge and careers, and introduce new scientific concepts in national systems.

Capacity building was an area of strength for many grantees, which suggests there could be opportunities to translate cross-grant project learning into a systematic approach for capacity building that could be applicable across country contexts and adopted by future grantees. Grantees may need more support measuring and articulating the impacts of capacity building.

Recommendations

A systematic approach for capacity building could include a standardized assessment of the short- and longer-term outcomes of capacity building – completion of graduate studies, obtaining employment in the agronomic sector, maintenance of research capabilities and continuing to conduct research activities to support agronomic solutions, how the training met needs, and how the training was used. This information would help to inform the foundation of the short- and long-term impacts of capacity building, and could be used to make changes or updates to how grantees approach capacity building.

A systematic model may hold the potential for the foundation to develop a community of practice of scientists and students, trained in digital agronomic research and practices that could enable cross-country and cross-crop learnings, and would help to sustain regional, national and international collaborations developed during the grant project period. The foundation could also offer more study tour funds or more concrete support/resources to operationalize collaboration among networks.

The foundation could consider developing a system for cross-grant project learning related to capacity building for researchers. Many online survey responses, in particular, support this recommendation.

The most transformative part of grantees' research was the inclusion of data-driven approaches in research. Incorporating the data-driven piece into research had the potential to rapidly develop location-specific agronomy solutions.

All grantees were involved in extensive data collection and digital data management activities as part of their research. Data-driven approaches for this evaluation refers to the use of data that can speak to small-area variations or tailored solutions and come from household surveys, large numbers of soil samples, field trials conducted at many sites, and feedback loops; this data is then compared to satellite and other outside data sources such as weather, market data, or other agronomy data.

For grantees these approaches included digital data collection modalities, developing agronomic datasets and databases, soil mapping and DSTs available via mobile application. DSTs provide farmers with site-specific recommendations based on information held in crop and soil databases collected for each country. They help farmers make planting, fertilizer and other farm-related decisions based on more accurate information and recommendations. Incorporating large data-driven components into research is a change from previous approaches to agronomy, where research institutes developed and released new varieties or new recommendations, without any ability to tailor them to regions or specific farmer needs. Using large datasets can help account for local differences, farmer behaviors, and available credit.

CSISA: Landscape Diagnostic Survey (LDS) Research Activity in India

Perhaps the most significant project that CSISA, KVKs, and ICAR undertook was the LDS, a household survey on rice and wheat production carried out over five states (Bihar, Chhattisgarh, Odisha, Uttar Pradesh, and West Bengal). KVK officers administered the survey using Open Data Kit (OPK), an Android-based app, to collect, transmit, and analyze data. Questions covered crop variety grown, yields gained, and style of planting (mechanized or manual). Two rounds of the LDS were carried out in Phase III, and CSISA hopes to institutionalize the LDS within ICAR and the KVKs to achieve the project's objective of building capacity for scientific research and evaluation. As of 2019, "data from 7,648 wheat fields and 10,069 rice fields [had] been uploaded" to the server of the Indian Agricultural Statistics Research Institute, who will analyze and publish data in the future (CSISA III_Narrative-31Dec19, pg. 9).

Most notably, TAMASA and ACAI collected and developed extensive datasets to inform the development of their decision support tools. ACAI focused on digital research using open source software (e.g., R statistical software package) and trained local researchers on digital data collection in the field including how to use Open Data Kit Collect on mobile devices and QGIS (an open source alternative to ArcGIS). CSISA implemented the LDS to collect data from over 40,000 farming households, and SBPEA is still collecting data to inform the development of its decision support tool. These data sets and tools were developed to potentially help government ministries of agriculture (and extension services), the private sector, and agro-dealers better understand the needs of farmers. However, the use of the data within the large datasets developed by grantees appears to be limited at this point. Additionally, gaps in capacity exist within grant project countries related to collecting, organizing and storing the data, which may take some time to address.

TAMASA: Agronomic Panel Survey (APS) Research in Ethiopia

One of TAMASA's main sources of data, the APS, was a yearly household survey that measured "agronomic, yield and soil components... at the time of harvest." Each panel consisted of ~750 households, and was carried out thrice in Ethiopia and Nigeria, and twice in Tanzania. Researchers sought to find maximum efficiency in plant density for a country and compare it to the regional recommendation of 55,000 plants/ha. In Ethiopia, APS research found the "optimum plant density is about 65,000 plants /ha," while in Nigeria, research found efficient density depended on seed variety (early, medium, long duration) and soil nitrogen levels.

ACAI, TAMASA, SBPEA (all single-phase grantees that had a key focus on DST development) most clearly demonstrated cross grantee collaboration and sharing of knowledge related to DSTs. These collaborations were described in project reports, mentioned as a project benefit by stakeholders in interviews, and cited in M&E data. Both TAMASA and SBPEA collaborated with ACAI and planned to use ACAI's data platform in their own DSTs, saving both the time and expense of finding a digital business partner to develop their own platforms. This collaboration also allowed more consistency across grant projects in approaches to DSTs.

Implications/Reflections:

Large-scale data-driven research shows promise to move agronomy from focusing on plant breeding and developing new varieties to understanding how these agronomic solutions and technologies interact with farmers' behaviors and motivations.

The issue with large datasets is balancing data exploration with hypothesis testing in order to make full use of the data. Data exploration involves comparing all of the different data points, which may result in a large number of associations, many of which may be spurious. Hypothesis testing, in contrast, involves analyzing the data to answer specific agronomy questions. For example, does early sown wheat increase yield and farmer income? Are certain fertilizers better for different soil types?

Grantees appeared to be focused on collecting the data but not sufficiently focused on the life and use of the data once collected. They are collecting and generating data sets that could potentially be put to powerful use, but there is an under-utilization of the data. Including feedback loops, particularly with feedback from farmers, early in the process of developing agronomic solutions could make agronomy solutions more usable for farmers and address any constraints or challenges to farmers' data use early in the development process. However, the time needed to collect and then analyze data can present challenges in making data available for use in a timely manner.

Recommendations:

The foundation should consider improved ways to build capacity to analyze large data (e.g., effective machine learning techniques and how to follow up the resulting hypotheses with further research), standardize merging of different data sources (e.g., household- or farm-level data and satellite imagery data), and communicate findings.

With grantees reporting having to store data in open-sourced repositories and having difficulties with data quality and standardization of data management practices, the Findable Accessible Interoperable Reusable (FAIR) data principles may provide useful guidelines. Especially as grantees work across diverse geographies and with a number of research institutes in different countries, FAIR data principles could support future grantees in their efforts to improve data standards and data sharing capabilities. Another option would be to support partnerships between grantees and the national statistics agencies where they operate, which would build off support from other donors and encourage collaboration among agencies at the national level.

FAIR DATA PRINCIPLES

The Findable Accessible Interoperable Reusable (FAIR) data principles can be instrumental in streamlining data assets and processes to improve data use and management at the grant level and across grants. FAIR data principles are guiding principles that promote data findability and access, and data interoperability and reusability.

To improve data findability, FAIR principles promote the use of unique identifiers for metadata and datasets, the description of context and characteristics of metadata, and the indexing of datasets so they can be easily sourced online. FAIR principles aim to improve data accessibility by using open-source data repositories, while interoperability is supported by advocating for the use of data exchange formats that can be used on other systems. To increase reusability of data, the principles aim to optimize the use of data attributes, and user rights.

The foundation seeks to move more of its funding in agronomy to address systemic issues in the research system to accelerate learning, scale innovative tools and approaches, and continue to use solutions based large datasets, thereby increase the efficiency and effectiveness of research. Standardizing data approaches around FAIR data principles could help support this process.

5.2. Common Challenges

Grantees faced challenges on budgeting/balancing enough time for all grant project priorities including: conducting the research, translating research into agronomic solutions, and assessing and incorporating the need to address potential constraints. Additional challenges included capacity for digital data management.

As seen in M&E data and grantee documents, and discussed in interviews, grantees needed more time to conduct their research. This was primarily because of problems with data collection and management, and because the solutions developed uncovered additional issues that needed to be resolved, extending the timeline for development. For example, TAMASA had to build capacity in local researchers for digital data collection and management, and had to deal with unanticipated data quality issues. ACAI faced delays due to an unsupportive environment for its development of a cassava fertilizer blend: the government regulations restricted the importation of bulk fertilizer materials.

Timing was a particular issue for single-phase grant projects – SBPEA, TAMASA, and ACAI – which had shorter funding periods to conduct proposed activities than multi-phase grant projects did.

The tailored agronomy solutions developed by grantees faced a number of common agronomic constraints (discussed in more detail in Chapter 6 on Scaling), including requiring farmer inputs, farmer credit, labor, and mechanization.

In interviews and grantee documents, several grantees described challenges in conducting digital research and developing digital data solutions, because of a lack of in-country understanding and skills in digital data management. It is unclear whether grantees did not adequately assess in-country expertise in this area or did not have the time to adequately help in-country partners build these skills. During interviews, grantees expressed concerns about the capacity of partner organizations to continue digital data collection after the end of the grant project.

Implications/Reflections:

As many in-country research partners had limited to no experience with digital data collection and digital data management in the agronomy sector, several grant projects had to work very closely with researchers and research institutes to develop these skills. However, grantees still expressed concerns about the ability of these organizations to continue digital data collection and management beyond the life of the project, which may imply that these countries and/or partners were just not quite ready to embrace and implement digital data solutions.

As discussed in Chapter 4, an assessment of potential constraints appeared to be only a limited part of needs assessments. Better understanding of these constraints and addressing them during the development phase might have improved dissemination and use of agronomic solutions.

Recommendations:

Grantees may need guidance on assessment of partner and country readiness for digital data solutions, anticipating potential constraints on implementing developed solutions, and guidance on setting reasonable targets and goals, given the timeframe for their grant projects and the available resources. Five years was too short a time to move from idea to research to widespread implementation, and the foundation could work with grantees in the beginning of the funding period to realistically plan out grant project activities.

While all grant projects produced GPGs,[8] the number and type of GPGs produced varied by grantee, and the impact of these public goods on the agronomy sector was unclear.

Common examples of GPGs developed by grantees included numbers of graduate students trained, agronomic tools or solutions developed and disseminated for use, research articles and reports published, and digital datasets, soil mapping and DSTs made publicly available.

Grantees described the publication and dissemination of these tools and datasets in interviews and grantee documents and throughout the M&E data. Generally, multi-phase grantees (CSISA, N2Africa) produced much larger numbers of published articles, reports and tools disseminated. However, as a grantee primarily focused on research, TAMASA (single-phase grantee) produced a substantial number of datasets and publications. It may be that the major focus on research by TAMASA, as compared to the other single-phase grantees (ACAI, SBPEA), who focused on research but also on activities beyond the research stage, allowed TAMASA to produce this level of GPGs.

Grantees clearly emphasized the production of GPGs. However, the actual use of GPGs remained unclear: across grant projects, no data sources mentioned their use. For example, it is unclear how many grantees have data on external use of the datasets developed, which may mean that, as with DSTs, the production of GPGs was not a priority for many grantees.

Almost all interview respondents were unfamiliar with the term "global public goods," and were unable to describe connections between availability of GPGs and the impact GPGs produced on the agronomy sector within grant project countries. It may be that at the project level, with limited implementation time and limited skills and resources for monitoring of GPG use, having these types of impacts is just not feasible.

Implications/Reflections:

If the purpose of producing GPGs is to have data, tools, and research made publicly available, tracking use and ease of use may provide information on which GPGs are of greater interest or use. This information could help inform grantees and the foundation about how to target their products, and what changes they need to make to datasets, reports, tools and publications to make them more accessible and useful for the public and other target audiences.

Recommendations:

The foundation should consider developing a systematic method for documenting and disseminating information on GPGs, and communicate to grantees the importance to the foundation of this part of their work. The foundation could include this communication in

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[8] While the foundation may move to focus on the term "transferrable assets" instead of global public goods, at the time of this assessment we used the definition cited earlier in the chapter when making our assessment of global public goods developed by grantees.

submission instructions for grant project proposals. The foundation could also provide concrete support to researchers for distributing and publicizing GPGs, such as conference and journal submissions, presentations, and study tours. Another possible model is a repository of GPGs produced by grant projects, centrally managed by the foundation or another international research institution.

This central management could remove responsibility for monitoring from the project level, allowing projects to focus on implementation. Regular assessments of GPG use could help to identify gaps in GPGs for countries, crops, and key stakeholders, and help inform future funding strategies, as the foundation could easily understand which products were well used and where needs existed.

Grant projects could use this repository and data use information when developing their own GPGs. Existing tools and products could be quickly and easily accessed, and could serve as models and help grantees understand which tools or products may be of greater interest to the intended audiences for the GPGs – whether other researchers, policymakers, extension agents, or farmers. This type of centralized system could also more easily facilitate cross-grantee learning, a key piece that was missing from much of the work of the grantees in this portfolio.

6. Scaling

For this evaluation, **scaling** means expanding, replicating, disseminating and adapting successful agronomy solutions to reach a greater number of beneficiaries or **target users**.

The **dissemination of agronomy solutions** is the widespread distribution of recommendations, tools and technologies that emerged from agronomic research to **target users** or beneficiaries.

In the framework for this evaluation, scaling also includes **capacity-development for dissemination partners** – developing or improving the ability of grant project partners to disseminate and scale agronomy solutions. Partner-led networks disseminate technologies and products to farmers to help them enhance efficiency and the productivity of their farming activities. Partners need this training to build capacity on how to use, or help farmers use, the solutions; support the distribution of tools and technologies; and assess and respond to farmer needs.

KEY FINDINGS

- Involving scaling partners, both public and private, was a key part of the scaling and dissemination work of the grantees, and all grantees used similar methods to increase capacity of partners to use technologies and tools.
- Grantees often **started scaling activities later than originally scheduled**, due to longer than planned time needed for research activities, and faced challenges in trying to scale their approaches before their grant period ended (ACAI, TAMASA, SBPEA). These challenges were experienced in particular related to the scaling of decision support tools (DSTs).
- For several grantees (N2Africa, ACAI, SBPEA), **input, market system and value chain issues** affected grantees' ability to scale their work.
- Grantees that focused on one crop (the single-phase grantees – SBPEA, TAMASA, ACAI) might have **missed the opportunity to approach scaling through a more systematic lens**.

This chapter includes a discussion across grant projects on the **scaling** activities that were part of the grantees' work. We present the discussion by common features across grant projects, challenges, and then key conclusions/recommendations. Examples of innovations, unique contributions and promising practices by individual grant projects related to development are highlighted in text boxes in the common features section. Findings are synthesized across data sources and include data from the document review, interviews, online survey and M&E data. More detail on the work of each grantee related to **scaling** is provided in Appendix B.

6.1. Common Features Across Grant Projects

Involving scaling partners, both public and private, was a key part of the scaling and dissemination work of the grantees, and all grantees used similar methods to increase capacity of partners to use technologies and tools.

Scaling partners or agents were slightly different for each grantee, but generally included public sector partners such as government agencies or institutes and extension agents, and private sector partners such as seed, fertilizer and inoculant companies and NGOs. Other scaling partners included service providers, commercial seed multipliers, processors, and farmers' groups or associations

All grant projects used similar methods to increase capacity of **scaling partners** (both public and private sector) to use and disseminate technologies and tools. Methods included training of trainers, field demonstrations, and collaborations with farmers groups. Scaling partners used a combination of similar approaches to reach **farmers** and scale agronomy solutions to expand their work to more farmers or extension agents, including farmer field days, demonstration plots, and farmer associations (SBPEA, CSISA, N2Africa).

CSISA: Dissemination Strategies

CSISA's focus shifted from research to emphasize dissemination. The LDS highlighted that farmers were not implementing many of the government-recommended practices (seed varieties, fertilizers, etc.), and helped the agronomy sector realize that it needed to pay more attention to the dissemination of research results and recommendations. CSISA's practice of developing a cooperative "ecosystem for the adoptability of the technology" [CSISA Stakeholder] provides a model for this new way of thinking about dissemination.

N2Africa: Disseminating Seeds and Inoculants

N2Africa had originally planned for private sector partners to take the lead on disseminating seeds, but encountered problems obtaining high-quality seeds in time. The project thus relied on more informal and customary seed multiplication methods, mainly using farmers as multipliers. N2Africa established a system that more or less ran like a bank: farmers who received seed from the project were "encouraged to repay 2 kg of seed for every kg of seed received back to the project for redistribution to other farmers" (2009-2013 Final Report, pg. 66).

N2Africa also worked with seed companies and community-based seed producers (including farmer groups) to produce and distribute certified and quality-declared soy, groundnut, cowpea, and common bean seeds. The project helped support inoculant production, mainly for soybeans, in several countries.

In each project country, public and private sector partners either imported or produced inoculants, which were then distributed by private agro-dealers, farmer groups, and others. N2Africa exceeded their target inoculant sales for the cumulative project period. In 2018, most sales occurred in Ethiopia and Nigeria.

These scaling practices, including numbers of farmers reached and numbers of partners trained, were well documented in grantee M&E data. Results from the survey data showed that across grant projects the vast majority of stakeholders (94%) felt that the grant project improved the capacity of extension agents to conduct scaling activities. When asked about changes the grant project could make to improve the capacity of extension agents to promote and disseminate new tools for farmers, survey respondents most highly ranked increasing training on tools, giving extension agents incentives to promote the tools the grantees had developed, and involving private sector partners with more-relevant business models.

SBPEA: Dissemination of Banana Varieties

The recipients of the disseminated varieties included 84 farmers, six seed multipliers, and three institutions in Nakaseke; 30 farmers and four commercial seed multipliers in Rwimi; and 10 farmers and one institution in Birere. Each farmer received 60 suckers: 10 of each cultivar. They were mandated to produce and give out at least two suckers from each cultivar to another farmer in their group. The institutions received the same number of suckers, which they used to establish demonstration plots. The commercial seed multipliers received more plantlets than those received by individual farmers and institutions; these seed multipliers were mandated to establish mother gardens from which they would multiply plants and sell seed to those in need.

SBPEA: Scaling Partnerships

SBPEA relied on a variety of partnerships to carry out their work. In SBPEA reporting, these partners are referred to as scaling agents who broadly fit into the following clusters: "government, NGOs, farmers' groups or associations, FM radios centers, and private sector." SBPEA partnered with 70 scaling agents across Uganda and Tanzania, and implemented a scaling strategy developed in collaboration with these partners. This strategy involved:

- **Mobilization,** including radio shows and meetings with farmers and farmer groups
- **Active engagement,** including training of trainers, demonstration plots, and communication tools
- **Showcasing,** including farmer field days and radio shows
- **Integrated monitoring,** including farm-level checks, stakeholder meetings, and "documentation of success stories"

SBPEA developed easy-to-distribute communication products such as material hand-outs, radio broadcasts, and posters in both Uganda and Tanzania. A majority of materials were developed in English and translated to Kiswahili (Tanzania) and Luganda and Runyakitara (Uganda), which allowed the project to have a wider reach beyond the target regions and to have consistent messages across communication vehicles. In Uganda, radio campaigns included questions that farmers answered via text message. This provided a way for project officials to gain data on farmer priorities over a large population; 20,525 Ugandans texted responses to radio poll questions. From this activity, SBPEA learned that though banana is an important crop for many farmers, access (or lack thereof) to capital hindered farmers' ability to "[adopt] key productivity improvement technologies."

SBPEA also used other avenues to communicate with farmers across Uganda and Tanzania, including a SBPEA-produced film (in collaboration with CABI) entitled *Banana and I*. The project also used **digital media**, including a project website (www.banagron.com), Facebook (https://www.facebook.com/groups/385107745368421/), and Twitter (https://twitter.com/AgronomyBanana). The development, testing and deployment of **communication tools** including "banana story chart[s], extension guide[s], dramas [and] radio programs."

Because SBPEA developed hybrid approaches to managing pests and soil fertility, the project reached a variety of farmers across scale and income levels. The project also viewed farmers as partners rather than recipients, working with farmer groups and using farmers to duplicate and disseminate new varieties of banana. Partners and stakeholders worked together to educate farmers on research products and technologies, particularly the scaling agents.

Implications/Reflections:

Grantees all used similar approaches to disseminate and scale agronomy solutions, and these were obviously familiar to grantees and well documented in M&E data. Partners were a key piece of dissemination and scaling work: involving known dissemination partners that had experience in scaling agronomy solutions appeared to be important for scaling, and was dependent on the focus of the work of the grantee. Private sector partnerships were important for disseminating some of the fertilizer, seed and inoculant solutions, while public and private sector partnerships were essential for engaging extension agents.

Several grantees appeared to have approaches to scaling that worked well, as highlighted in text boxes above. These practices included working with strong dissemination partners, involving them equally from the start of the project, and ensuring that they were a funded partner in the grant project activities. This involvement allowed consistent messaging across communication channels. These were also partners who were able to focus exclusively on the dissemination part of the grantee activities. Additional promising practices may be using some type of incentive to motivate extension agents to disseminate tools, and using business models to better involve private sector partners.

While grantees easily documented numbers reached and trained, the extent to which the extension agents and farmers promoted and adopted these solutions is unknown. This issue is discussed in more detail in Impacts in Chapter 8.

Recommendations

The foundation should provide direct funding or incentives to scaling partners either as part of the grant project or separately, ensuring early involvement of these partners and collaboration from the beginning of the funding period. The foundation should encourage and promote these partnerships, and help grant projects identify key dissemination partners that have local knowledge, technical expertise, and experience with agronomy scaling practices.

Funding implementation or scaling separately from a research project should be done with caution, however, and for agronomy solutions with high potential for impact. Some of the more profound insights from the five research grant projects reviewed for this evaluation involved 'demand-driven' and 'farmer centric' research, and fully divorcing research from its practical application could move the grant projects away from incorporating a demand-driven focus.

It may be useful to develop standard measures of success for scaling that can easily translate into numbers that adopted or promoted the agronomy solutions.

6.2. Common Challenges

Grantees often started scaling activities later than originally scheduled, due to longer than planned time needed for research activities, and faced challenges in trying to scale their approaches before their grant project period ended (ACAI, TAMASA, SBPEA). This was especially true for the scaling of DSTs.

As discussed under Development in Chapter 5, many of the single-phase grantees needed more time than planned to conduct research. As these grantees worked to conduct research for digital applications of agronomy solutions, they encountered delays in completing their research and subsequently the scaling activities, because of problems in developing data platforms, lack of staff with the capacity to manage data, and difficulty conducting the necessary field trials. For these reasons the grantees ran out of time to fully scale their solutions and technologies.

Interview respondents and grantee documents described problems with the reliability and coverage of in-country telecommunication networks; political and regulatory environments; administration of public institutions; and the literacy of target users and beneficiaries, all of which interfered with the scaling of DSTs. Grantees engaged key private sector actors to help, which required additional time. Farmers also had difficulties in estimating plot sizes (CSISA, ACAI) and accurately estimating crop performance *without* fertilizer or herbicide application. This makes it difficult or impossible to obtain correct fertilizer recommendations. Over- or underestimation of fertilizer needs in turn creates inaccurate assessments of investment costs for farmers, which makes it difficult to scale the technology as it is not useful for the farmer.

The online survey confirmed findings from interviews and grantee documents. The survey asked respondents to select and rank the most important barriers to DSTs' adoption by farmers. Overall, respondents ranked farmers' limited understanding on how to operate DSTs as the most important barrier, closely followed by the limited reach of dissemination networks. Lack of participation from the private sector was ranked third. Lack of adequate cellular networks and cost of accessing DSTs were ranked fourth and fifth respectively.

One aspect that survey respondents did not perceive as an important barrier was the limited quality of the recommendations (for fertilizer, for example) from the DSTs. This may imply that the respondents gave high ratings to the quality of research conducted under the grant project and the development of site-specific recommendations.

Both N2Africa and CSISA to date have not scaled their DSTs, for reasons that were unclear from grantee documents and interviews. Additional conversations with these two grantees revealed that N2Africa did develop a prototype of a publicly accessible DST by the end of Phase II but that future hosting, use and development will depend on continued interest from users and stakeholders. CSISA was unable to identify a scaling or business strategy to move the DST technology beyond the pilot stage. SBPEA reported stopping the development of a DST focused on market timing after farmers were unwilling to implement a soil management technique that was a key part of the DST. Interviewees reported that SBPEA was continuing to gather data to inform another DST, though the data was behind schedule.

Implications/Reflections:

While scaling agronomy solutions requires adequate time and planning, scaling DSTs had challenges that go beyond the typical scaling challenges faced in agronomy.

In many developing country contexts, use of DST apps is still low, pointing to the need for better understanding of farmer demand. In a review of mobile agricultural services in Africa, Emeana et al. (2020) find that most pilot projects seeking to promote use of DSTs eventually fail, in part due to costs: after nonprofits withdraw financial support many farmers can no longer afford to use DSTs, and therefore stop. Similar issues were found for the DSTs in our evaluation – they were costly to develop and maintain, and many farmers were unable to use them without ongoing assistance.

In a separate review, Baumüller (2018) finds problems with the way that demand for digital technologies is assessed. Usually, phone-based services are rated according to smallholder self-reports. In addition, very few studies examine smallholder farmers' use of the app and the relationships between use of it and outcomes such as production and income. None of the grant projects in this portfolio documented farmers' use of the DST app, nor did they gather data on use and impact, which also may not have been part of their original charge in developing the DST. Further research could investigate the success rate for apps developed with and without external financial support.[9]

Recommendations:

Plans for scaling should begin early and be part of the initial needs assessments grantees conduct, so that adequate time is allocated for scaling and for addressing potential infrastructure and external factors that can negatively affect scaling.

As using digital agronomy solutions to introduce efficiencies and improve scalability will continue to be a part the foundation's future work in agronomy, the foundation should do a broad assessment of what works and what does not work related to digital agronomy solutions, particularly DST apps, in a variety of countries.

The larger, foundational grant projects (N2Africa, CSISA) did not scale digital DST apps during the project period. The reasons for this could be explored in greater detail, and lessons learned held up for future grantees. For example, CSISA stopped its work on "Crop Manager" in India, despite an already existing infrastructure that appeared supportive of digital app solutions. In India, where most farmers of all sizes have smart phones and a certain level of digital literacy,

[9] See the Consultative Group for International Agricultural Research's Platform for Big Data in Agriculture for a convening platform organizing relevant data and success stories: https://bigdata.cgiar.org/.

there is an extensive cellular network even in remote rural areas, so an infrastructure exists that appears to easily support the use of digital apps. How can the foundation learn from an example such as CSISA?

Improving use of DSTs involves both policy changes at a country level and user-friendly, simple solutions to scalability at an individual level. The Malabo Montpellier Panel's "Byte by Byte" report (2019) provides relevant policy proposals to improve digitalization in agriculture: address safety concerns through regulatory environments; provide digital literacy training; increase fiscal incentives and investment in digital solutions and last-mile (to farmers) infrastructure; and evaluate needs and impact. Successful organizations point to the importance of user-friendly, simple solutions for scalability.

Many DSTs, including those targeted for advisory services, need to do more to engage farmers in research and assess farmer demand. MacMillan and Benton (2014) argue that innovation and input through financially independent phone apps is lagging in the developing world. In many developed countries farmers provide regular feedback and ratings to apps to further their development; however, this is not the case for farmers in developing countries.

In thinking about approaches to scaling DSTs, the foundation should require grant projects to build in ways to assess and receive this type of feedback from farmers and target users, and to better assess farmer demand for digital solutions, which may help to address challenges around scaling. Similar to findings in Chapter 4, developing and scaling useful DSTs may be more successful if research savvy partners are paired with digital partners at the start of the funding period rather than expecting individual grantees to be responsible for all aspects of the DSTs.

A fundamental question for the foundation is the degree to which its grantees should participate in and focus on scaling of DSTs. While the grant projects in this portfolio felt it was part of their charge to scale DSTs, it may not be a key goal of the foundation in funding this research. Scaling expectations for DSTs should be made clear to grant projects at the start of their funding period.

For several grantees (N2Africa, ACAI, SBPEA), there were input, market system and value chain issues that affected the grantees' ability to scale their work.

Limited market access to particular inputs and lack of available financing challenges broadly included agronomy solutions that required large initial financial investments, the use of inputs unfamiliar to farmers (herbicides, pesticides and fertilizers), costly or hard-to-access mechanization, and large labor requirements that were costly and time-intensive, all of which made farmers hesitant to adopt the technologies.

Respondents from the key informant interviews reported that farmers were unfamiliar with the use of fertilizer, herbicides, and pesticides within their cropping systems (ACAI, SPBEA) and were also reluctant to use these inputs due to costs and potential health risks. Efforts to promote these techniques required investments in training, and sensitization on the merits and importance of correct and safe use of these inputs. Extension workers were often also insufficiently aware of how to use inputs, and required training.

Price volatility complicated grantees' efforts to build markets for their technologies, according to multiple interview respondents. They referred to instances where a drop in global crop prices caused local demand to decrease (N2Africa), which subsequently forced local input and crop prices to drop, discouraging local production, and therefore demand for inputs (fertilizer and inoculants).

For some grantees, unintended consequences from the introduction of agronomy solution that improved crop yields included the possibility of creating a "market glut," where a number of farmers in any given area experience considerable yield increases, and the potential for supply to outpace demand. That can decrease farmer interest in continuing to implement technologies and tools in a situation where their investments cannot be realized due to low market prices for their crops. ACAI and SBPEA both experienced market gluts that accompanied increases in crop production and decreases in market prices for the crop, which made scaling efforts difficult. Both grantees had to address this in order to continue to engage farmers in their work.

When encountering scaling issues, grantees realized they had to rely on a market systems approach, and focused on creating a functioning supply chain by building public-private partnerships that linked farmer cooperatives to agro-dealers, processors, and fertilizer or seed companies (N2Africa, SBPEA, ACAI). While grantees worked to increase awareness and demand for technologies (e.g., rhizobial inoculants, fertilizers, seeds, soil and nutrient management technologies), building a market and supply chain to drive adoption of technology was difficult. Building linkages, connecting input suppliers (e.g., fertilizer blending companies) with the demand side (farmers and farmer groups), and connecting offtakers (e.g., processors) facilitated collaboration and interdependence, and created opportunities for scaling.

Implications/Reflections:

While the focus of the grantees' work was on research and on developing agronomy solutions from the research, all grantees also realized they needed to include a scaling approach to disseminate the solutions and encourage adoption.

For many grantees, this approach required creating demand and awareness for the solutions, and addressing common technology adoption challenges faced by farmers: lack of capital, risk aversion, unfamiliarity with solutions and/or lack of available mechanization, labor, markets, etc. The need to first create awareness and demand might have hampered the scaling of some of the tools and recommendations. The need to create demand leaves a question of whether or not the initial research conducted by the grantee was actually demand-driven as intended, and whether a key part of any agronomy solution should build in ways to address these common challenges. These challenges are well known and not new to the field, and addressing them should be part of any initial or ongoing needs assessments.

Strengthening the value chain may require helping to ensure supply, such as through seed producers, certification, and distribution, as well as downstream market linkages. It is also worthwhile to be thoughtful about where and when to scale. Also, sometimes it can make more sense to begin scaling with those who are not the primary target, e.g. larger farmers versus smallholders, to create a market and sufficient scale to make it profitable for private actors and to provide a demonstration effect (USAID 2018). For this evaluation, this reflection may suggest that grantees may just not have the skills or capacity to engage in value chain development and a consortium approach may more easily achieve value chain strengthening.

Recommendations:

While grant projects had a key focus on conducting research, the foundation could fund future grantees with an emphasis on a market system and value chain approach as part of their scaling activities. This may require a longer funding period than provided to many of the single-phase grant projects in this portfolio (typically five years). While grant projects were essentially made

up of researchers, who might not have had experience in these approaches, the foundation could fund scaling partners and others that could help guide grantees in these areas.

There are common ways to address the well-known, longstanding challenges faced by farmers when implementing agronomy solutions, particularly through the function of the needs assessments and literature reviews. If grantees start by building a better understanding of the usual challenges faced, they can design to these challenges, rather than having to remediate once these challenges are encountered. The foundation should help develop key ways to address these challenges, and help grantees anticipate what these challenges might be and how to best address them for their country, crop, and target users.

The foundation should consider incorporating a toolkit or other guidance in requirements for grantees related to scaling. One example may by the Agricultural Sustainability Assessment Toolkit. This toolkit provides more-concrete guidance on scaling, and on criteria to use to decide whether scaling is likely to succeed. It scores each innovation by its importance to developing priorities; credibility and observability of the innovation with key stakeholders; how easily it can be tried, purchased, adopted, and implemented effectively; its potential benefits or business case for adopters; its business case for value chain actors; the strength of the overall market system; and the public sector enabling environment.

The toolkit also provides a roadmap for thinking through scaling by determining who should drive the scaling process on an ongoing basis. It points out that private sector actors, while preferred, are not always suited to driving scaling – especially where value chain actors are weak and/or missing. In such cases donors can help by building awareness, creating demand, providing training and technical support, and introducing financial systems to enable the producers' ability to pay (USAID 2018).

Grantees that focused on one crop (the single-phase grantees – SBPEA, TAMASA, ACAI) may have missed the opportunity to approach scaling through a more systematic lens.

Interview respondents discussed scaling challenges related to focusing on single crops, as was the case for ACAI (cassava), SBPEA (bananas), and TAMASA (maize). This challenge was also discussed by some CSISA interviewees. The challenge was primarily described in the interviews, and did not emerge from other data sources.

While a concentrated focus on a single crop did not hinder extension agents' ability to provide support for that particular crop (or others), interviewees said that building on agronomy solutions that work for one crop, expanding these solutions to other crops, and promoting solutions that worked for multiple types of crops may have better scaling success – scaling agents and extension workers could bundle solutions and promote them to farmers as working across crops. By bundling messages and technologies across crops, scaling agents could reach more farmers – instead of having to focus on separate recommendations for each type of farmer and crop, they could spend resources on sending bundled messages out to more farmers.

Limitations with focusing on single crops were seen as grant projects began to address market system and value chain challenges. Respondents recommended looking at successful scaling models for other in-county crops, building upon lessons learned from scaling of those crops and integrating the grant project work into systems already developed for scaling. They suggested collaboration with existing farmers groups and cooperatives. These methods could allow for better returns on investments for farmers, encouraging further scaling of agronomy solutions.

They also suggested there might be benefits in learning from scaling work with other in-country crops (for example, coffee) that had built successful private sector engagement and business models regarding the non-traditional use of crops, and applying these lessons more broadly.

Implications/Reflections:

There are both benefits and disadvantages to concentrating research on one crop. A single-crop focus, while needed for the research behind developing tailored agronomy solutions, particularly for the specificity required by DST apps, presented additional challenges when grantees moved to scaling.

Grantees did have some success in bundling different agronomy solutions for the same crop, but may see greater scaling benefits from bundling similar solutions across crops, where scaling and extension agents can better use resources, reach more farmers, and engage farmers more easily. For example, if extension agents are trying to promote/disseminate a new banana technology, but farmers are more immediately concerned about their other crops, being able to address solutions across crops can better engage the farmer. Sometimes scaling is made possible through bundling technologies, and makes new technologies more attractive to private actors than unbundled strategies alone.

In many ways, scaling approaches could benefit from a multi-crop focus, particularly when thinking about ways to create awareness and demand for solutions and addressing market system challenges. A multi-crop focus may allow grantees to take advantage of pooling potential economies of scale, and bring a better return on investments in solutions for farmers, thereby encouraging continued use and scaling of solutions.

Recommendations:

In future funding strategies, the foundation should consider some of the benefits of a multi-crop approach to agronomy solutions and how to help grantees build some of these benefits into their scaling approaches, particularly during initial needs assessments. It may mean that the foundation will have to expressly fund scaling partners that have experience in solutions used with other crops, and consider how these crops have created demand and built value chain and market system approaches that the grant project could build from.

The foundation will have to consider how large a role scaling will play in its funding strategies. There are many ways that the foundation could provide guidance on scaling based on lessons learned from work with other crops, particularly in-country learning.

7. Institutionalization, Policy Development and Sustainability

Agronomy research, tools and technologies can be **institutionalized** or made a part of the permanent work of key international and national research organizations and governments. They can also be integrated into the work of other private or public groups or agencies working in agronomy research. **Institutionalizing** agronomy research and agronomy solutions (recommendations, tools and/or technologies) makes it more likely that these developments will continue beyond the life of a grant project. **Institutionalizing** the work of grantees is one way to help ensure **sustainability** of agronomy research and solutions.

Policy development is an important step in **sustaining** the work of a grant project beyond its implementation period. **Policy development** can help to create an enabling or supportive political or regulatory environment for improved agronomy practices and value chain development. **Policy development** may be development of an administrative policy that changes practices and procedures or the development of a policy by a national or local governing body through a legislative process.

Policy development and **institutionalization** are integral parts of **sustainability** and often happen simultaneously or in tandem. **Sustainability**, for the purpose of this evaluation, relates to activities continuing after the end of the funding period for the grant project. For purposes of this evaluation, **we consider sustainability in two ways.**

- First, **target users'** (beneficiaries') continued employment of an **agronomy solution** after the end of the grant project indicates **sustained use of that the solution**.
  - We do not differentiate within this definition whether increased use of the solution is sustained versus current (or any) use of the solution is sustained.
  - Further, for this evaluation, we do not consider the timeframe; ideally, use would occur until a new, better agronomy solution replaces the grantee-developed solution. However, grantees measured neither the rate of uptake of a solution nor the timeframe of use of a solution after the grant project has ended.
  - Proxy measures for sustainability of agronomy solution include whether or not an implementing partner (e.g., NGO or private sector company) has taken up the agronomy solution, an institution within the government has formally assumed responsibility for promoting the agronomy solution, and similar metrics that a non-grantee actor had the intention of continuing to use or promote the agronomy solution.
- Second, **researchers'** continued pursuit of the **agronomy research** started under the grant project indicates **sustainability of research**.
  - Again, for purposes of this evaluation, we cannot assess the scale, scope, or timeframe of the continued research, which would provide a deeper understanding of the extent of research sustainability.
  - We therefore **use similar proxy indicators for sustainability** – whether or not a research institute within the country officially (in some form) took over the research during the grant period or as the grant project ended.

This chapter includes a discussion across grantees on the **policy development, institutionalization** and **sustainability** of their work. We present the discussion by common features across grant projects, challenges, and then key conclusions. Innovations, unique contributions and promising practices by individual grantees are highlighted in text boxes in each section. Findings are synthesized across data sources and include data from the document review, interviews and M&E data. The online survey did not include questions on **policy development, sustainability** or **institutionalization**, so this chapter does not include findings from that survey. More detail on the work of each grantee is provided in Appendix B.

KEY FINDINGS

- Grantees that could **build on work conducted in previous funding periods** (N2Africa, CSISA, and ACAI) **were better able to show achievements** in policy development than other grants (TAMASA, SBPEA) that had only one funding cycle.
- Grantees **built linkages with public and private sector partners**, and engaged in building a market for their agronomy solutions to better sustain their work.
- Most grant projects **lacked a clear plan for institutionalization**, and only began exploring options and undertaking active measures to institutionalize when they reached the final stages of the funding period.
- While **capacity building was considered an important step to facilitate institutionalization**, grant projects expressed concern about the capacity of the institutes designated to adopt the agronomy solutions, particularly with regard to sustaining the data management, maintenance and updates of data sets and technologies.

7.1. Common Features Across Grant Projects

Grantees that could build on work conducted in previous funding periods (N2Africa, CSISA, and ACAI) were better able to show achievements in policy development than other grantees (TAMASA, SBPEA) that had only one funding cycle.

Grantees undertook advocacy and policy reform efforts to promote policies and regulations that aligned with the interest of value chain partners. The intensity of these efforts and the level of success across grant projects differed. N2Africa, CSISA and ACAI actively worked with partners to promote and advocate for policies and regulatory environments to support the sustainability of agronomy research and agronomy solutions.

N2Africa grantee documentation and interview respondents reported that inoculants were not registered in some of their focus countries, and that as a result of a lack of regulation, inoculant-related research activities were difficult to conduct. CSISA and ACAI also reported that a policy environment influenced their ability to develop and sustain their agronomy solutions. While CSISA faced subsidy regulations that limited the adoption of the promotion of zero tillage in India, ACAI encountered a policy that constrained the import of bulk fertilizer components, which delayed the grantee's ability to develop the desired cassava fertilizer blend.

N2Africa: National Policy

N2Africa was involved in developing a national inoculants policy in Ethiopia and helped develop a biofertilizer policy, which, as of the 2019 Annual Report, had yet to be endorsed by the government. In 2019, N2Africa developed policy recommendations for Tanzania and Ethiopia after consultations with stakeholders, including a 10-point policy recommendation for the legume value chain, addressing areas such as production, extension, co-ops, consumption, markets and government institutions.

Multi-phase grantees with longer investment periods (CSISA, N2Africa) had the additional time needed to consider how policies could help support their strategies, and to cultivate public and private relationships to influence and support policy development. In addition, ACAI built upon the work of an earlier grant project, Cassava Weed Management Project, to support regulations on the import of the herbicide Paraquat and to promote alternative and safer herbicides in Nigeria.

However, while the grant projects in this portfolio were designed to build off lessons learned from earlier grant projects, there appeared to be limited sharing across grant projects related to policy development, institutionalization and sustainability.

Implications/Reflections:

Policy development often occurs after time spent understanding regulatory environments and how to address challenges to scaling and dissemination, developing data to demonstrate the need for a policy and cultivating relationships with key partners that can support or advocate for policy. Studies recommend policy reforms that increase private sector participation, quality and safety standards, privatization, and improved institutional and financial frameworks. National policies can reduce barriers to inputs, increase access to finance, improve governance and provide incentives such as export processing zones (Brubaker et al., 2013).

CSISA: Regional Policy

CSISA Phase II worked closely with the regional government in Bihar, which incorporated early sown wheat into its annual recommendations. CSISA leaders had established national and international recognition within the agriculture community, which helped them develop partnerships. CSISA worked to collaborate with the state governments of Odisha and Bihar to streamline policies on mechanization. Additionally, in 2016, Bihar adopted CSISA's recommendation of "expanding area under DSR [directly seeded rice] as a state priority[and] tips on DSR [were] endorsed by the Odisha State Department of Agriculture."

Multi-phase grantees, and grantees that could build off the work of earlier foundation-funded grant projects had better success in getting to the stage of developing and influencing policies that helped create supportive regulatory environments for their activities.

Recommendations:

The foundation should do an in-depth analysis of the process that CSISA and N2Africa used to develop policies, and provide new grantees with a toolkit or a model of this step-by-step process. Similarly, best practices could be shared across grant projects to help address challenges related to policy development. The foundation could facilitate this cross-grantee learning at key points in the funding period.

The foundation could also consider integrating Collaborative, Learning and Adapting approaches or frameworks as part of their grantee portfolios. These approaches would benefit both grantees (e.g., by sharing lessons) and the foundation in spotting/understanding systemic issues that it could try to address with cross-cutting support for grant projects, or through thought leadership from the foundation itself.

Grantees built linkages with public and private sector partners and engaged in building a market for their agronomy solutions to better sustain their work.

Interview respondents and the grantee documents described extensive public-private partnerships by almost all grantees. Interview respondents described how for some grantees (N2Africa, CSISA) these relationships were so extensive, often stretching across multiple countries, that it made partnerships hard to manage and required extensive time and effort from grantees. It is unclear why grantees partnered so extensively, how useful the numerous partnerships were, and whether or not extensive partnerships were encouraged or promoted by the foundation.

CSISA: Partners and Institutionalization

Interview respondents also pointed out that **CSISA** did not just focus on farmers but also made concerted efforts to build partnerships, share communications, and develop common understanding across partners in different sectors and levels – including local, state, and national government, universities, agricultural extension agencies (KVKs), NGOs, private sector, media, and farmers. This reflected a limit on what CSISA could do by itself and CSISA's recognition of need for existing institutions to buy into programs for sustainability

Partnership building also required dynamic human resources. Respondents at all levels (national, provincial, and district) commented on the expertise, quality, and responsiveness of CSISA staff.

Grantees engaged public sector partners to help create supportive regulatory environments and build public sector capacity for developing and sustaining research and dissemination and scaling of solutions, as discussed in more detail in other parts of this chapter.

As grantees moved beyond the research phase of their work and began to think more about scaling, sustainability and institutionalization, most started to engage more private partners to help with creating and sustaining markets for technologies, and providing finances to continue grant activities beyond the life of grant.

To help address the need for continued finances and resources, some grantees adopted a value chain development approach (e.g., N2Africa, SBPEA) creating linkages between farmers, agro-dealers, processors, service providers (CSISA) and other value chain actors to help support farmers in the long-term.

However, this work was not without challenges. To create a sustainable market for legume technologies (e.g., inoculants), N2Africa, for example, aimed to bring together demand and supply markets. On the demand-side, interview respondents reported a steady increase in the awareness of and demand for inoculants across focus countries. On the supply-side, agro-dealers were wary of stocking inoculants owing to the limited shelf-life. As manufacturing inoculants is a low-value and low-margin business, local producers also had few incentives to scale production as a result of competitive international manufacturers.

SBPEA: Creating Sustainable Markets

As the project progressed, **SBPEA** began to see rapid increases in banana production attributed to farmers' uptake of the project's technologies, SBPEA realized that "the market is a key driver to production." Witnessing market prices for bananas drop, farmers were discouraged from using the technologies the project promoted. The project had assumed during the proposal phase that the private sector would be interested in investing in banana markets, but due to the bulkiness and perishability of banana crops, and the distance between market (mainly urban) and production zones, there was a reluctance from the private sector to make the investments needed to support increased banana production.

SBPEA intensified their collaboration with partners to encourage and support farmers groups and banana cooperatives, building on existing in-country (Uganda) models that exist for coffee growers, as ways to promote sustainability by pooling crops and better negotiating national and international prices for crops, and pooling resources to access more affordable transportation to distant markets.

Among grantees that had a major focus on agronomy research and developing DSTs (ACAI, TAMASA and to some degree SBPEA), these grantees realized they needed to create a business model for the full development and ongoing sustainability of the DSTs they had developed. A business model laid out the steps needed to commercialize and finance the DSTs. Grantees involved private sector organizations to develop the data platform for the DSTs and for the continued financing of the research, data updates and continued maintenance of the DSTs.

These grantees had only limited success in finding a partner who could adopt the DST (TAMASA), or faced uncertainty about whether partners had sufficient incentives to maintain the delivery of these tools (ACAI). SBPEA was still working on the development of their DSTs at the time of this evaluation, but provided little detail about how their partners would continue to market the DSTs beyond the life of the project.

Implications/reflections:

As described throughout this report, developing and maintaining partnerships was a key function of each of the grant projects. Grantees spent enormous amounts of time and resources in developing and maintaining key partnerships that supported their work. While partnerships were a key component in the work of grantees, many interview respondents were unclear on how the relationships and partner momentum gained under the leadership of the grant project would be sustained.

Building linkages with partners in the private sector can create trust in the technologies and increase their commitment to continue delivery after the grant projects end. These partners need sufficient profit incentives and viable manufacturing and distribution channels for continued dissemination.

Studies also show the importance of ensuring the financial sustainability of organizations that used to receive support – and ideally, building a diverse support base from the beginning – as well as clear communication about timeline, handover of responsibilities, and the way in which financing will wind down (Petrovich, 2011).

Recommendations:

A key piece of policy development, institutionalization, and sustainability is facilitating collaborations with public and private institutes and organizations. Studies have shown the importance of translating agronomy research into policy and the importance of carefully selecting partners in country with whom to develop relationships (Hazell and Slade, 2016).

Developing and sustaining partnerships beyond the life of the grant project may require the foundation to rethink its current funding approach. One question to ask is, how can the foundation more broadly facilitate and fund public partnerships across countries that could be used to sustain the work of multiple grant projects? The foundation could also provide guidance on developing and managing partnerships, and how to limit partnerships to those most needed or most useful for grant projects to sustain their work.

Developing business models was a key component for those grant projects developing DSTs, and most grantees also engaged private sector companies to sustain their technologies. The foundation could provide steps or frameworks for grantees to follow when developing business models and a timeline for when grantees need to start developing these models.

7.2. Common Challenges

Most grant projects lacked a clear plan for institutionalization and only began exploring options and undertaking active measures to institutionalize when they reached the final stages of the funding period.

This lack of an institutionalization plan was particularly true for the single-phase grantees – TAMASA, ACAI and SBPEA – who had approximately a five-year funding period.

Grantees conducted large-scale agronomy research, including extensive multi-locational data collection and analysis, and development of decision support frameworks, which often spanned multiple countries and consumed most of the projects' resources in the first few years of the funding period. They also experienced unforeseen challenges related to data collection, staff skill sets, and the development of the prediction engines that underlie the DSTs.

Delays in research caused delays in the development of agronomy solutions. These delays, combined with not having a clear plan for institutionalization of their work from the start of their grant project, left single-phase grantees trying to sustain and institutionalize their work late in the funding period. Unfortunately, this late focus on sustainability made it difficult for grantees' work to be sustained beyond the grant period.

The need to engage the private sector and develop business models, particularly for DSTs, also appeared to be a late realization for grantees. Grant projects struggled to create sustainable business models for a variety of reasons, including external challenges with developing markets for relatively new and low-profit inputs, policy and regulatory environments, price volatility, and creating awareness and sufficient demand for these technologies and practices.

Another consideration is the overall ability of research grantees to develop policy, and scale, institutionalize and sustain their work. While this issue is not mentioned in grantee documents or in M&E data, a small number of interview respondents noted that developing sustainable business models, policies and long-term institutionalization plans was not part of the skill set of the research team funded under these grant projects.

Implications/Reflections:

The experiences of the grantees demonstrate the importance of implementing a carefully conceived exit strategy, which includes the identification of institutionalization and sustainability plans early in the grant project implementation period.

Institutionalization and sustainability need to be part of the early work of the grantees, preferably during the planning period or during an early needs assessment. Early incorporation of these plans allows grantees to identify key processes and partners that are essential for sustainability. Early planning can help to ensure grantees are prioritizing sustainability of their work from the beginning of the funding period and can help determine in-country and public institute capacity for sustaining grantee activities.

Recommendations:

Ensuring the sustainability of agronomy research and solutions is challenging, especially for grant projects with relatively short investment windows. A United States Agency for International Development (USAID) Office of Food for Peace study found four common pillars that helped reinforce sustainability based on lessons learned with phasing out development food assistance projects, which we consider broadly applicable beyond food assistance programming. The four factors considered critical to project sustainability were: (1) a sustained source of

resources for each activity previously provided by the project such as adoption of profitable business models or provision of government funds, (2) mechanisms to sustain technical and managerial capacity, (3) a continued source of motivation for service providers and beneficiaries such as financial incentives that can maintain supply and demand, and, (4) linkages to NGOs and/or other entities; this was imperative for successful phase-over of responsibilities (Rogers et al., 2015).

The foundation could consider the Office of Food for Peace factors or similar frameworks as part of a systematic approach to sustainability that future funding strategies and/or future grant projects would be required to incorporate. The foundation should encourage grantees to develop a (tentative) roadmap to institutionalization and sustainability at the project design stage and during an initial needs assessment.

While capacity building was considered an important step to facilitate institutionalization, grant projects expressed concern about the capacity of the institutes designated to adopt the agronomy solutions, particularly with regard to sustaining the data management, maintenance and updates of data sets and technologies.

As described in detail earlier in this report in Chapter 5, all grantees included some type of capacity building in their work. Conducting capacity building activities, setting targets for these activities, and reaching these targets were described and emphasized in the document review, M&E data and by interview respondents.

Capacity building is important to ensure that projects can be sustained after donors leave and can help to facilitate institutionalization of research grant projects, by ensuring in-country capacity for understanding and conducting research, and continuing to build upon grant project research.

SBEA: Funding to Public Research Institution

An important advantage held by SBPEA, compared to the other grants, is that SBPEA operates out of the National Agricultural Research Organization (NARO), a public institution providing guidance and coordination of all agricultural research activities in the Ugandan agricultural research system. This allows SBPEA to ensure that its research is aligned with the priorities of the agricultural research system and more easily facilitates institutionalization of its technologies.

Although capacity building was considered an important step to facilitate institutionalization, uncertainty remained about the adequacy of skills and sufficiency of resources of public institutes to continue the work of the grant projects. This concern was mentioned specifically by interview respondents from CSISA, TAMASA and ACAI. See Appendix B for specific examples from interviews from these grant projects. Without adequate capacity, it is difficult for grant project activities to be sustained in certain countries.

Grantees were engaged in transformative agronomy research which required skillsets not commonly available in the agronomy sector (e.g., geospatial analysis). Phasing over the responsibility to continue the agronomy research and/or maintain the data infrastructure of DSTs relies on advanced skillsets that grantees may not be able to develop in time before the grant project expires.

While all grantees reached targets for training researchers and graduate students, there was little discussion by interview respondents on the connection between this type of capacity building and sustainability. This lack of connection may indicate limited understanding by key stakeholders or limited emphasis by the grantee on the potential role of training students in

sustaining grant project activities. None of the data sources indicated whether these students obtained employment in the agronomy sector of the countries where the grantees worked, a measure often used to indicate a step towards sustainability in the sector.

Implications/Reflections:

For many of the data-driven approaches tested by grantees in this portfolio, public institutions had limited capacity, resources, political will, and technical skills to update and maintain grantee developed databases and research technologies. Grant projects need to better evaluate the required level of capacity building efforts for sustainability of research and agronomy solutions.

Recommendations:

The foundation should consider how to better support these public institutes as long-term sustainability partners. One way to do this could be using different funding models. For example, the foundation may want to consider supporting national research institutes with general funding rather than project specific funding. This approach may allow these institutes to generally improve capacity and skills that could be broadly applied across multiple grant projects and/or other types of research, allowing for easier sustainability of agronomy research and solutions.

In addition, grantees may need support in measuring institutional capacity for sustainability and how to better understand the connection between capacity building and sustainability. As discussed elsewhere in this report, these approaches (changes in funding, measures) could most likely benefit from a more systematic model for sustainability that could be applied across grant projects.

8. Impacts

The final step in the framework is impact. This part of the framework focuses on **increased technology adoption by farmers**, **strengthened supply chains,** and **improved farmer productivity.** Implicit in these three components is a definition of **impact** that links research grant projects to (institutionalization – see Chapter 7) changes in agricultural practices (scaling – see Chapter 6) to produce more-efficient supply chains and production processes and thereby improve the lives of farmers and other value chain actors. Impacts described in this chapter are primarily based on grantee and stakeholder perceptions of impact articulated in interviews and reports. Because each grant project had a different focus and different key activities, and there were no uniform impact goals or target outcomes across grant projects, impacts and outcomes cannot be compared across grant projects.

The impact indicator of increased technology adoption by farmers reflects farmers' use of an agronomy solution. For example, this could include using and following the recommendations of a DST or using a recommended sowing technique.

Supply chains describe the activities needed to create a product or service and move the product or service to the final consumer. **Strengthened supply chains**, then, refers to a new solution that improves the efficiency, effectiveness, or responsiveness of the supply chain. While many aspects of supply chains are outside the immediate purview of agronomy research, we should see actors in the supply chain (e.g., extension agents, private companies) adopting supply chain strengthening innovations that grantees developed or tested; that would be our measure of impact.

Improved farmer productivity specifcally relates to crop yields. However, increasing famrer productivity should also result in increasing farmers' income and profits.

KEY FINDINGS

- All projects developed agronomic insights or innovations that led to **increased yields**, and most reported some **adoption of agronomic innovations among farmers**.
- During in-depth interviews, most grantees discussed their **impact on the field of agronomy research** in addition to or instead of their impact on target users (such as farmers).
- Grantees **did not comprehensively measure impact**.

This chapter includes a discussion across grant projects on the **impacts** that were part of the grantees' work. We present the discussion by common features across grant projects, and key challenges. Examples of innovations, unique contributions and promising practices by individual grant projects related to impacts are highlighted in text boxes. Findings are synthesized across data sources and include data from the document review, interviews, online survey and M&E (especially results tracker) data. More detail on the work of each grantee related to **impacts** is provided in Appendix B.

8.1. Common Features Across Grant Projects

The foundation required grantees (excepting N2Africa Phase I), at the beginning of grant projects, to define **impacts** within a theory of change (e.g., "we will develop X technology, which will improve the livelihoods of farmers by doing Y") that laid out the logic of how they expected the grant project to have impact. Many grantees, however, did not set **targets** for their

impact (e.g., Technology X will reach Z number of farmers and increase their yield by ##%), and/or did not measure the metrics that they used to define their potential impact. Thus, we are not able to assess whether the projects had their intended impacts.

All grant projects developed agronomic insights or innovations that led to increased yields, and most reported some adoption of agronomic innovations among farmers.

M&E data that do exist for grant projects demonstrated various discoveries on how certain crop varietals or agricultural inputs performed in a field trial setting (Appendix A1 discusses M&E data in more detail). All five grant projects demonstrated agronomic solutions that increased yields (see either the development chapter or reference the appendices). To some extent, routine grantee monitoring data or evaluations showed that farmers across the projects adopted these technologies, although the number of farmers using the DSTs under TAMASA was small, at least in Ethiopia. The other four grantees all estimated to some degree the number of farmers using technologies. During Phase II, CSISA, at USAID's behest, used GIS images and key stakeholder interviews to estimate uptake in over 2 million households. ACAI reported the number of farmers benefiting from DST information, although, because ACAI is still in implementation, final numbers are not available. SBPEA, also still in implementation, reported the number of farmers it reached, but interview respondents thought this number underestimated the indirect effects of SBPEA. Only N2Africa conducted a formal post-hoc quasi-experimental evaluation of impact. Results of this evaluation do suggest impact (see call-out box). Generally, the numbers of farmers reached by the shorter-term grant projects (TAMASA, and, with data available for this evaluation, ACAI and SBPEA) were, to the extent measured, far more modest than the numbers reached by the longer-term grant projects (CSISA, N2Africa).

N2Africa: Impact Evaluation Results in Ethiopia

Results from N2Africa's quasi-experimental impact evaluation show that, compared with farmers who had not received direct project support, farmers who had were more likely to adopt a combination of improved legume varieties and inoculant (28.1% of supported farmers did this) and more likely to use fertilizer and inoculant (16.9% of supported farmers did this). Among adopters, legume productivity increased by 83.5 kg/ha. In total, income received from all crop sales increased by $166.

Implications/Reflections:

Reviewing only five grant projects, three of which were still in implementation and with limited data measuring impacts, this evaluation cannot define types of interventions with a greater likelihood of success, or specific activities that increase the likelihood of a grant project having an impact. However, based on the limited data, it appears that grant projects with longer time horizons were better able to demonstrate measurable impacts. Respondents also suggested that thinking about dissemination and scaling methods early in the grant project period helped to create the intended impacts.

Only N2Africa conducted a formal impact evaluation. As discussed in more detail below, the expectations for the grantee should determine whether or not to measure impacts, given that it is often costly to do so. However, if the decision is to measure impacts, the foundation and grantees should understand the uses for the measurement of impact. There are multiple potential reasons to measure impacts, including demonstrating that an agronomic solution works, to provide evidence to inform efforts to institutionalize and scale the solution, and determining variation in uptake to inform future dissemination and targeting strategies. These considerations will

determine the type, scale, and timing of the efforts to measure impacts, whether or not a formal evaluation should be employed, and ultimately the cost of measuring impact.

Recommendations:

If the grant project activities are expected, at the beginning of the grant project, to have an impact at scale within the grant project timeframe, then grantees should think through measuring that impact from the beginning of the grant project.

During in-depth interviews, most grantees discussed their impact on the field of agronomy research in addition to or instead of their impact on target users (such as farmers).

Respondents from all five grant projects stated that they believed their activities had impacted knowledge and/or "shifted the thinking" about agronomy. Respondents pointed to "demand-driven research," engaging farmers in research, "big data," multi-location assessments, application of digital technology, assessing multiple inputs or crops simultaneously (see call-out box for an example from CSISA), and incorporating feedback loops, as types of shifts in thinking that they observed. Some of these innovations related to ensuring that research matches the needs of target users, while others represent new areas of exploration for the field of agronomy.

CSISA: Impact on Agronomy Sector in India

Respondents noted two areas where CSISA contributed to a shift in agronomy research in India. First, due to the success of the Green Revolution, agronomy research in India had typically focused on single commodities (for example, a new variety of seed). CSISA emphasized "systems thinking," considering the entire calendar year and the multiple and interacting inputs needed to improve overall yield across multiple commodities. The respondents observed a change in research from assessing a "single component's" effect on a single crop to assessing the combination of inputs that can increase productivity in all crops throughout the year. Changes related to continually assessing bottlenecks and seeking solutions to those bottlenecks accompanied this "systems thinking," along with more openness to multidisciplinary (e.g., anthropology, economics, political science) approaches to understanding and solving problems.

Second, agronomy shifted to an increased emphasis on dissemination. The LDS highlighted that farmers were not implementing many of the government-recommended technologies (e.g., seed varieties, fertilizers), and helped agronomy researchers realize that they needed to pay more attention to the dissemination of research results and recommendations. One stakeholder noted, "Previously it was research first and extension follows, but now through the CSISA project it is that extension and research are happening at the same time."

Implications/Reflections:

Certainly, the goal of agronomic research is impact on farmers or similar actors in the agricultural system, and the foundation's insistence that research take into consideration target users' needs affected how grantees conducted research, and helped to encourage new ways of thinking that considered, for example, local areas and target user needs. However, the impact of research grant projects on agronomy and agronomy research reflects the expertise of the staff, and is often more within the control of the grantees than is the impact on farmers. Identifying and describing impacts on agronomy research – changes in the types of questions asked and methods (including dissemination) used – separately from impacts on target users may help to foster continuous agronomic innovation. The sustainability of research innovations may be less "market-driven" than for agronomic solutions that affect farmers' productivity and profits directly, and therefore requires identification of institutes to carry on the research. CSISA, for example, identified government institutions (e.g., KVK and statistical agencies.) to help implement the LDS, and worked to secure funding for its continued implementation through these bodies.

Recommendations:
Grantees should continue to assess target users' uptake of research solutions.

Other recommendations concerning the sustainability of agronomy research are discussed in Chapter 7 under Section 7.2.

8.2. Common Challenges

Grantees Did Not Comprehensively Measure Impact.
As noted above, M&E data from the Results Frameworks was somewhat sparse when it came to data that measured impact as we define it in this chapter. Each project's M&E plan included a Results Framework, which set the project's indicators of progress and targets for these indicators, and a Results Tracker, which detailed progress made towards these targets over time. Our review of the indicators and targets across the five grant projects indicates that on average about 49% of targets set were met, and 28% of targets were not met (Table 5). Three of the grant projects were still in progress at the time of the review, and likely will meet more targets before the end of the grant period. Appendix B discusses the reasons why goals were not met.

Generally, reasons related to encountering obstacles or not having sufficient time. However, setting ambitious targets and coming close to meeting them, but ultimately failing, can be better than setting very modest goals and exceeding them. Thus, unmet targets do not necessarily reflect failures, since most of the targets not met were, in fact, *partially* met. In our judgement, for 23% of targets either the achievement of these was not measured or the goal-setting lacked sufficient clarity to determine whether or not the target had been met. Lack of clarity in M&E indicators or in the achievement of targets represents, minimally, poor M&E systems and an inability to truly track progress of activities.

Table 5. Results measurement across the five grant projects

	Target exceeded	Target met	Target not met	Target or measurement of target lacks clarity	Target or measurement of target missing	Total targets
N2 Africa Phase II	10 (40%)	9 (36%)	3 (12%)	1 (4%)	2 (8%)	25
CSISA Phase II	4 (13%)	6 (20%)	3 (10%)	16 (53%)	2 (7%)	30
CSISA Phase III	2 (3%)	33 (57%)	16 (28%)	4 (7%)	3 (5%)	58
SBPEA		15 (50%)	15 (50%)			30
TAMASA	1 (3%)	4 (13%)	15 (47%)	11 (34%)	1 (3%)	32
ACAI	10 (26%)	13 (34%)	8 (21%)	7 (18%)		38
Average	14%	35%	28%	19%	4%	

As noted above,M&E data that existed generally focused on outputs, such as number of people trained and number of field trials conducted, rather than macro-level impacts such as adoption or percent change in yield or income (with the exception of N2Africa). However, we classify few of the targets as "impact" indicators; N2Africa reported on five indicators that measured impact as we define it in this chapter (see Appendix B), while other projects reported on one or no impact indicators. With the exception of N2Africa, projects with one impact indicator had not met the targets associated with the impact indicators at the time of this evaluation.

Implications/Reflections:

Developing a theory of change that includes the potential impact of research on target users (e.g., farmers, value chain actors) justifies the investment in a research grant. However, for inception grant projects – grants for projects looking at new crops or systems that have not had previous research grants – impacts on farmers may not be a realistic expectation. By including in results trackers indicators and targets about impacts for grant projects, project planners run the risk that failure to achieve targets about impact may overshadow actual and tangible achievements of the grantees. However, current frameworks reflect work done (e.g., "people trained"), but do not capture whether or not the "work done" led to a next step (e.g., the people trained gained knowledge and did something with that knowledge). Failure to capture whether "work done" led to a next step also makes it difficult to articulate the value of the grantees' actual achievements, and potentially undersells the achievements of the grantees' work.

In some cases, failiure to meet targets reflected a flawed theory of change, and researchers had to step back and reflect more broadly on the context of the challenge. Agronomists across the five grant projects started to embrace or fully embraced "systems thinking" in their research. N2Africa used a systems thinking approach based on earlier work and a variety of publications. Systems thinking had different meanings to researchers in different grant projects. For example, for some researchers it meant thinking about all crops and their interactions within a calendar year, while for others it meant thinking about the value chain, its actors and the incentives they faced, while for some it also may have meant thinking about the effects of government policies and regulations. Anticipating and setting up research to capture and understand these types of phenomena will improve projects' ability to develop solutions that meet the needs of the target users. In tandem with operationally oriented research, grant projects also started to embrace multidisciplinary research – bringing in, for example, agricultural economists, behavioral economists and anthropologists, geographers, and statisticians to formulate and conduct research alongside the agronomist.

Recommendations:

Recipients of research grant projects should develop results frameworks and indicators that reflect the needs of the *immediate* target users of agronomy solutions (which may not always be farmers), and whether the activities of the project met their need. Further, the foundation should consider including considerations of system thinking in grantee proposals, and in the articulation of theories of change.

9. Conclusions and Recommendations

9.1. Recommendations for Better Understanding and Meeting Existing Research Demand and Target Users' Needs

Use Demand-Driven Approaches to Agronomy Research

The success of agronomy research depends on the extent to which it meets the needs of partners and target users. A deep engagement of potential partners and target users during the design stage is essential to develop a demand-driven agronomy research agenda and co-create agronomy solutions that are rooted in a clear understanding of the user's characteristics, needs, and challenges. The information gathered during the design stage feeds into identification and prioritization of agronomy research, but testing and development of agronomy solutions requires continuous engagement of partners and target users to develop demand-driven solutions. Demand-driven agronomy research thus relies on both a comprehensive needs assessment as well as the integration of feedback loops throughout the life-cycle of the project.

Grantees must also balance the requirements of the foundation with needs of partners and target users. While grantees did focus on a data-driven approach to their grant activities, particularly with the focus on developing DSTs, many grantee organizations and their partners did not have the experience, capacity or knowledge on how to manage large data sets, conduct digital data collection and develop and maintain digital data platforms. The beneficiaries, farmers, also often did not have the digital capacity to directly use tools, requiring grantees to rethink the target user for DSTs. As part of the demand-driven approach to research, grantees and the foundation should work together to assess grantee, country and beneficiary capacity and demand for digital approaches.

Conduct Comprehensive Needs Assessment as a Driver for Demand-Driven Agronomy Research

A comprehensive needs assessment at the design stage of the project will help to ensure that the agronomy research is aligned with target user needs and to warrant the use of results. Needs assessments should include targeted stakeholders such as scaling partners, private and non-profit sector partners, NARS scientists, and farmers or farmer associations.

As the ultimate beneficiaries of the agronomy research, farmers should be directly consulted about their perception on key constrains, hurdles to profitability, and proposed agronomy solutions. This will not only ensure that agronomy research will lead to solutions that reflect the true demand of target users, but will also build farmers' trust in the tools and technologies developed by the grantee. SBPEA, for example, viewed farmers as partners and prioritized their agronomy research with inputs from a baseline survey with the aim to profile constraints and opportunities to tailor agronomy solutions to specific segments of farmers.

The deep involvement of scaling partners, private and non-profit sector partners, and public sector institutions would also provide opportunities to identify scaling pathways and potential challenges to reach sustainability. While the inclusion of these partners in needs assessments is critical to identify key bottlenecks to farm productivity, and adoption of technologies, their early involvement also allows a grantee to assess the extent of their capacity and available resources to support the agronomy research. Moreover, most grant projects identified NARS institutes as playing a key role in mainstreaming and institutionalizing agronomy solutions; creating buy-in is therefore important.

Integrate Feedback Loops

Grant projects should consider systematically integrating feedback loops to help ensure the delivery of demand-driven and high-value products to target users and to provide opportunities to test and adjust agronomy solutions. N2Africa developed this approach in Phase I and implemented it in Phase II. Following ex ante needs assessments, some grant projects sought subsequent feedback from partners and target users throughout the project cycle. Incorporating feedback from partners and target users on, for example, results from agronomy research, prototypes versions of DSTs, or best ways to communicate recommendations, not only guarantees that agronomy solutions meet the needs of target users, it also fosters relationships with partners whose extensive engagement would increase buy-in to actively participate in scaling technologies. Seeking feedback from partners and target users, however, is time consuming and could slow down progress. Grant projects would have to require partners to invest time and resources in this process and eventually integrate the solutions offered into their operational strategies.

Commit to Gender Equality in Prioritization of Agronomy Research

Grant projects need to integrate gender perspectives into ex ante assessments and prioritization of agronomy research. Most grant projects recognized gender inequalities in access to agricultural inputs, technologies, and extension services and aimed to address the needs of women. N2Africa, in particular, aimed to empower women by focusing on production of nutritionally improved legumes and labor-saving technologies. However, during the project design stage, grant projects did not explicitly identify challenges and opportunities women face or identify underlying causes of gender inequality in agronomic outcomes. Gender perspectives need to be integrated into ex ante assessments to identify how agronomy research and agronomy solutions could contribute to reducing gender gaps and how they will contribute to gender outcomes. The use of a theory of change may be considered to critically assess how a grantee's proposed activities could impact women differently than men and how it could contribute to better outcomes for women. With a better idea about the gender-differential impact, grant projects could consider adopting approaches that better address women's needs.

9.2. Recommendations on How to Better Innovate Ways to Do Agronomy at Scale and Increase the Return on the R&D Investments

Build linkages with a Broader Ecosystem of Service Providers

Linking farmers to a broader ecosystem of service providers such as credit services and input suppliers is critical for uptake and use of the grant's recommendations. Some grant projects (ACAI, TAMASA) were primarily focused on delivering agronomy recommendations to farmer communities using DSTs but with less consideration of the need to create market linkages. Apart from recommending farmers adopt agronomy practices (e.g. inter-cropping), DSTs and other technologies may also provide recommendations that require financial investments (e.g. fertilizer, labor, hybrid varieties). Grant projects that provide recommendations to farmers requiring inputs and/or financial investments, should more actively link farmers to other service providers, such as credit and input suppliers. At the dissemination and scaling stage, grant projects should consider facilitating market access to farmers as these grant projects start to provide recommendations to for example use a new fertilizer blend. Partners' extension networks, especially in areas with poor market infrastructure, may play a role in linking farmers to credit and inputs markets. This could not only lead to an increase in adoption of recommendations by farmers, but also to an increased interest in DSTs and recommended technologies which would ultimately increase the return on R&D investments.

Identify and Engage with Regulatory Dimensions and Assess Enabling Environments to Conduct Agronomy

Early identification of potential regulatory hurdles to the development and scaling of agronomy solutions is critical. During the project design stage, grantees recognized the necessity of a conducive enabling policy environment in target countries to be able to achieve intended agronomy outcomes. Hence, grantees, to varying degrees, involved policymakers and government institutions at different stages of the project. Grantees rarely conducted assessments, however, of constraints in the regulatory environment that may hamper R&D or scaling and/or areas for policy reform at the design stage of the projects. Difficult regulatory environments in some cases delayed the development of innovations. ACAI, for example, worked on a use case to develop a cassava fertilizer blend, but due to the government's regulatory restrictions on the import of bulk fertilizer materials, the development of a suitable fertilizer blend for cassava was delayed. CSISA, and to a lesser extent N2Africa, were notable exceptions as they dedicated considerable resources to the identification of policy reform opportunities, developed communication strategies for policy reform, and engaged in partnerships to reform policy. Nevertheless, while CSISA contributed to the evidence base to address India's fertilizer subsidy policies and aimed to develop a partnership to support policy reform efforts, they indicated that relatively low subsidies on zero tillage may have caused a lower than expected demand.

9.3. Recommendations on Efficiencies That Could Be Gained by Having a Common Platform or Shared Approach

Streamline Approaches to Data Collection and Management

Grant projects would benefit from a common approach to data collection and data management. As grant projects conduct innovative agronomy research, collecting data on a large scale across geographies and in complex environments, future investments should build on proven approaches to data collection, management, and storage. Grant projects that worked on developing DSTs, requiring large scale data collection, in particular faced challenges developing efficient ways to collect, manage, and store data. TAMASA, for example, noted that working with national research institutions on data collection and cleaning was substantially more difficult than anticipated, while ACAI encountered challenges with the capacity and willingness of national research institutions to use digital data collection tools (Open Data Kit). These examples show that grant projects intending to work with national research institutions on data collection must consider limited funding, capacity gaps, and the risk of shifting institutional demands on available resources that are difficult to foresee. Despite these challenges, grantees have developed a range of research protocols for multi-locational field experimentation and sampling frames, data processing procedures, data management systems, and approaches to data sharing (e.g., FAIR data principles). SBPEA demonstrated that there is an interest in utilizing proven approaches, working with ACAI and TAMASA to learn from their experience handling and managing data across a large number of field trials.

Similarly, grant projects would benefit from a common approach to M&E data collection with shared definitions and indicators to measure output and outcomes (see Section 9.5 below).

Create a Platform or More Centralized Approach to Facilitate Cross-learning

While grantees worked in unique contexts, focused on diverse value chains, and followed different implementation timelines, they faced common challenges in conducting agronomy R&D. A shared platform could facilitate more systematic and intensive collaboration across grantees and research centers. Our review provided very limited evidence of learning and

collaboration across grant projects, which may have limited grantees' ability to use proven practices, increase efficiency, and potentially improve outcomes. Some grantees, for example, faced similar challenges in conducting large-scale agronomy research, including field and validation trials, and developing site-specific recommendations. Similarly, for the development of decision support frameworks, grantees spent resources on content generation, developing software codes to generate site specific recommendations, and developing approaches to data management.

Apart from challenges to the implementation of agronomy research, a common platform could also facilitate more efficient ways to share best practices to implement comprehensive needs assessments, insights into effective approaches to scale agronomy solutions, or lessons learned from institutionalizing agronomy R&D. Furthermore, a common platform, housed in one or more of the participating research centers, could provide an opportunity to centralize tools, datasets, digital innovations, or literature which could promote learning and use across grants or research centers. Increased collaboration across grant projects or research centers, may also facilitate the sharing of technical expertise and make it easier to share resources to build capacity.

9.4. Recommendations on Increasing Sustainability, Efficiency, Scalability, and Mainstreaming the Outputs from the Grant Projects

Allow for Sufficient Time to Scale and Institutionalize Agronomy Solutions

Grant projects worked on a range of agronomy solutions, with some grant projects adapting proven solutions to new geographies, farming systems, or crops, and others developing new agronomy products. Given that these products have different time-lines to reach maturity, it is important to allow for sufficient time to scale and institutionalize agronomy solutions. In particular the commodity-specific grant projects, which commit to time-consuming R&D efforts, including extensive data collection, analysis, and generation of site-specific recommendations, emphasized the limited time to scale and institutionalize agronomy solutions. So while these grant projects deliver valuable products and recommendations, they face challenges with regards to achieving sustainability, partly as a result of time constraints. Hence, the length of investments should be considered in relation to the timing of scaling activities for future grant projects which aim to develop new products as these tend to have longer and often less predictable ways to mature.

Identify Pathways to Institutionalize and Sustain Agronomy Solutions at Project Design Stage

Findings showed the importance of identifying pathways to institutionalize agronomy solutions at the early stages of the grant projects. Institutionalization not only requires early identification and engagement of potential research institutes (e.g., NARS) who can maintain and potentially further develop agronomy solutions, these institutes also need to have the capacity, resources, and commitment to institutionalize the innovations. Although grant projects engaged research institutes in the agronomy research and conducted capacity development activities, there were concerns about the level of skills these research institutes could offer to maintain the agronomy solutions, or if they were sufficiently committed. An assessment of the capacity, resources, and commitment of institutes during the design stage as well as continuous engagement of these institutes to create ownership is critical. Grantees would need to determine whether they have the capacity and resources to conduct an assessment of potential institutionalization pathways. Furthermore, to ensure the interest of research institutes to institutionalize the agronomy

solutions at the end of project, grant projects should seek to align their priorities with research priorities of these institutes.

Leverage Business Models and Private Sector to Reach Scale and Sustainability

Ensuring sustainability often requires securing an alternative source of resources by the time funding expires. To sustain agronomy solutions beyond the life-span of the grant project, grantees need to identify business models that provide a route to sustainability. This may not only involve developing markets and building linkages and partnerships that feature the private sector for existing agronomy solutions, but also identifying a route to commercialization for newly developed agronomy solutions. All grant projects, to a varying degree, worked on building vertical linkages between farmers and scaling agents, agro-dealers, processors and other stakeholders to develop a sustainable market but were often confronted with challenges of bringing supply and demand together. On the supply-side, for example, N2Africa had difficulties developing a local market for inoculants as a result of low-profit margins and strong international competition, while on the demand-side, CSISA encountered lower than expected demand for zero tillage. When investing in new agronomy solutions, such as DSTs, grant projects would also benefit from laying out a route to commercialization to further improve access and continue dissemination. Developing an effective business model is challenging, especially in the relatively short times frames of the grant projects, but the development of an appropriate business model during the project design stage increases the potential to achieve sustainability.

Clearly Articulate Potential Sustainability Pathways in Project Designs

Following on the recommendations above, a sustainability plan and exit strategy should be embedded in the project design stage. Grant proposals often lacked specificity regarding strategies to reach sustainability. The foundation should consider requiring prospective awardees to include more detail on their strategies to achieve sustainability focusing on pathways through which the grant will affect long-term change. Future grantees could for example draw on lessons learned from existing conceptual frameworks for sustainability in planning exit strategies.

Translate Agronomy Advisory Materials into Multiple Local Languages to Encourage Uptake

To encourage uptake of agronomy advice and increase impact, timely translation of agronomy advisory materials in the appropriate local languages is recommended. Some grant projects translated materials late which led to a delay in dissemination of agronomy recommendations, or extension agents translating English materials in an attempt to share recommendations with farmers. This may pose challenges to scaling efforts, as a lack of content in local languages could inhibit effective communication of agronomy recommendations to farmers and may neglect the cultural context of the beneficiaries.

9.5. Improving the M&E Process

The study team used a manual process to review the M&E data, although a properly designed M&E system could be set up in such a way as to make these transformation functions automatic. For example, if grantees had been instructed from the beginning of the projects to break down their “blocks of text” into discrete outputs corresponding to different rows, the data would have been in a much better state for quick analysis. Additionally, the current Results Framework template is already set up with macros; a better template would have included macros that quickly consolidated any data inputted into numerical tables. This section of the Final Report contains recommendations on how to improve M&E systems.

Improve M&E Reporting Practices

As detailed in Appendix A1, these approaches could include the following:

- Create common indicators across projects.
- Develop specific protocols or procedures for collecting and calculating indicators.
- Put greater focus on "difficult to measure" impact indicators.
- Tie funding to the achievement of milestones that are further downstream.
- Incorporate legacy objectives.

Develop an Improved Platform for M&E reporting (as detailed in Appendix A) to enable improved, timelier M&E reports that are easier to analyze and visualize, and that better feed into project learning and adaptation.

Set Meaningful Targets

Review of the M&E data indicates that few programs collected data on impact indicators. Discussions with foundation staff indicate that the foundation did not necessarily want to hold research grantees responsible for impact indicators. Collecting and reporting only on output-level indicators is unsatisfactory, because it does not show whether or not the activities of a program are meaningful, only whether the program did the activity.

We recommend that grantees tie the M&E framework to the needs of the target audiences for the research or agronomy solution. For example, a grantee might undertake research to determine appropriate fertilizer use or some other agronomic solution, but not have the resources to disseminate the findings from that research widely. In that case, a target user – such as an NGO, or extension agents – should be defined as the mechanism for using and/or disseminating the agronomy solution, and the M&E framework should measure whether or not the research met the needs of the target user(s). The foundation may then, if they choose, consider evaluating the extent to which the target user used/disseminated the agronomy solution, and, then, whether or not farmers' behaviors changed.

Further, research is inherently an uncertain activity – timelines needed to achieve results are hard to predict, and in some cases it is difficult to assess ahead of time whether or not grantees can even achieve intended results. Allowing grantees to assess "risk" or "uncertainty" associated with targets, along with stating the assumptions made when they were setting targets, at the beginning of the program can provide a framework for documenting what was learned about the research process itself (and not just the learning associated with the end results of the research). Over time, this approach may improve the research process itself.

Shift the Approach to M&E to Include Demand-Centric Information

Current M&E systems are useful for project reporting and internal management. Respondents to the in-depth interviews reported using M&E data in meetings with foundation staff to help determine, discuss, and adjust program implementation. This is a useful function of M&E data. However, it is an inward-looking use of M&E data, focusing on the degree to which grantees are implementing plans, while allowing some adjustment for changing circumstances. Grantee staff from two different programs, when prompted about M&E, discussed meeting or having field visits with stakeholders and target users on a regular basis as the M&E method for their project.

This "outward-looking" method of assessing the progress of implementation is also referenced in the discussion of "Recommendations to Improve M&E of Grantees" – collecting data on how stakeholders and target users of agronomic solutions view, understand, and use the data would enable more impact-level indicators to be collected.

The study team recommends that the foundation incorporate, in a formal way, learning into the M&E framework. This will require that grantees define target audiences and target users for agronomy research and solutions, and solicit feedback from these groups on outputs, outcomes, and, potentially, impacts. Facilitation of feedback loops, when done correctly, enables continuous learning and adjustments, feeds into program planning and management decisions, and allows reported lessons learned to become a reported outcome in their own right.

Finally, external environments often have an influence on the outcomes and usefulness of M&E data, and it may be difficult to capture the effects of events such as political instability or droughts and how they impact grant outcomes.

9.6. Limitations

Many of the recommendations that focus on systematic approaches or recommend certain frameworks, as presented in chapters four through eight of this report, did not explicitly emerge from the evaluation findings. These are recommendations that could be useful and advantageous for the foundation when thinking how to move from asking individual grant projects to work on activities in each step of the framework to a more systematic funding strategy, but these recommendations have limited support from the evaluation findings, as they were not specifically stated in grantee documents or during interviews.

The other major limitation to this evaluation, as described briefly in Chapter 2, was the inability to conduct site visits and in-country interviews with key stakeholders and grantees due to travel restrictions from COVID-19. Spending a week or longer, as originally planned, in-country with each grant project would have allowed the evaluation team to have a more nuanced understanding of the work of the grant projects. While the single, hour long remote interviews with grantee staff and key stakeholders did provide valuable information for the evaluation, the evaluation team most likely could have gained better and more detailed insights from time spent in-country with grant projects.

Appendices Introduction

The appendices provide detailed information about the data collected for this evaluation. The first appendix (Appendix A) provides the methodologies used to collect and analyze data. The second appendix (Appendix A1) provides details on data collected when reviewing the M&E data from the grant projects. The next five Appendices (B1-B5) provide details for data collected for each of the five target grant projects (CSISA, N2Africa, TAMASA, ACAI, and SBPEA). Appendices C and D provide results and tables from the Geospatial Analysis. Appendix E shows results from the online survey and Appendix F provides the template used in the document review. Appendix G includes the external references used in this report

Appendix A: Methods for Data Sources

Desk Review Methods

The team completed a desk review of program- and country-level documents to gather information on the design, implementation, outcomes, and country context of each focal grant project. We analyzed the documents using a template to assess common themes, allowing for synthesis and comparison across grantees. We reviewed relevant program documents for each grantee and the supporting literature for those grantees: grant project reports for the five grantees; previously conducted analysis (CSISA) and stakeholder consultations (SBPEA, TAMASA, ACAI); grant project proposals; and M&E reports. The team reviewed additional reports and documentation as determined by our initial review of grantee documents provided by the foundation in order to more fully answer the evaluation questions. We also reviewed documents for other grantees as needed for background (e.g., African Soil Information Service and ISDA). In addition, we included approximately 20 recent peer-reviewed articles and/or reports on agronomy developments in sub-Saharan Africa and South Asia that are relevant to the value chains where the foundation made investments, those on best practices in agronomy, scaling, digital technologies and systems approaches.

Key Informant Interviews

To understand program implementation and performance at a grantee level, we conducted semi-structured key informant interviews for each of the five grantees. We interviewed four categories of key informants: (1) foundation staff, (2) agronomy experts, (3) national-level stakeholders, and (4) grantee staff and partners. The Abt team used three interview guides that were tailored to each sets of stakeholders (see Appendix B of the Inception Report for these interview guides).

While originally planned as in-person interviews that were part of site visits to four key countries that covered the five grant projects - Ethiopia (N2Africa and TAMASA), Nigeria (ACAI), Uganda (SBPEA), and India (CSISA), due to COVID19, the study team instead had to conduct almost all interviews remotely, using a combination of WebEx, Skype, What's App or direct calls to respondent's telephone. Two members of the study team spent four days in India, and were able to do a limited number of interviews in-person in India with grantee staff, partners, and farmers. However, these team members had to leave India quickly due to imposed travel restrictions by the Indian government and were unable to complete the full 2 week site visit.

For each of the grantee-specific respondents, we solicited a list of respondents from the PI for each grant and vetted and refined the list of interviewees based on foundation feedback and Abt team input. Except for foundation staff, we aimed to interview at least six respondents per respondent category (Table A1) to achieve adequate data saturation per respondent group. Foundation staff were foundation staff that managed current or related grant projects being assessed. Agronomy experts were external stakeholders that were not grant-specific. National stakeholders, grantees and staff stakeholders were affiliated with each grantee.

Our original goal for the evaluation was to conduct 81 interviews and we completed a total of 92 interviews across all respondent types and across all grantees (see Table A1). However, some of the limitations of conducting the interviews remotely included variability in the quality of the interviews due to poor audio quality of calls, dropped calls, and limited internet connectivity for some countries and some respondents. This issues were particularly seen in Ethiopia, where most

interviews had to be done via direct phone call, which usually resulted in the poorest quality of audio.

As originally planned, the information in the interviews would be supplemented by the in-country site visits which have allowed for more time with each respondent and provided the evaluation team with a more detailed and nuanced picture of the workings of each of the grant projects. However, without the opportunity to do the site visits due travel restrictions from COVID 19, both internationally and domestically within each country, information collected was more limited than originally anticipated.

Table A1. Interview sample size by respondent group

Respondent type	Cross-cutting	Across grant projects	Total
Foundation staff	3		3
Agronomy experts	6		6
Key stakeholders		49	49
Grantee staff		34	34
Total	8	83	92

Abt evaluators led these interviews. Interviews were all conducted in English due to the inability to do in-person interviews and the limited audio quality of the remote interviews, even in English. We documented interviews through audio recordings (with consent) and detailed interview notes. Recorded interviews were transcribed by an external transcription services. All data from interviews were transferred and stored securely using standard Abt data security procedures. The team developed an internal codebook in NVivo based along the three broad evaluation themes and questions. Abt trained six coders on the codebook and met regularly to review coding to ensure inter-coder reliability. We explored the data using thematic analysis to summarize common thematic patterns and identify outliers related to the evaluation questions and other topics of interest. We assigned coders RQs to code across grantees. Next, we conducted structured, theme-by-theme analysis in NVivo to answer the evaluation questions and help inform the case studies. Study team who conducted the interviews were responsible for synthesizing the findings form the theme-by-theme analysis and writing the key findings from the interviews.

Online Survey

The Abt team conducted the online survey to obtain a broader and more representative perspective of key stakeholders' opinions on grant achievements and challenges across the five grant projects included in this evaluation. In collaboration with the principal investigators of each grant project the study team developed a list of respondents for the survey which included grantee staff, implementing partners such as private and non-profit sector partners, government partners, and agronomic researchers. We only selected key stakeholders who were not enlisted to be interviewed such that we could gather structured data from a wider range of respondents. Interviewees included grant leaders and key partners that had more high-level, detailed information on all or most aspects of the grans, while the survey respondents were more distal and may have been less familiar with the grant and its overall purpose or process. To ensure low response burden, we collected data using a combination of Likert-scale and closed-ended questions, as well as open-ended questions which provided additional detail to qualify and clarify responses. Survey questions asked for respondent's perceptions on the grant's main challenges,

main achievements, demand and prioritization of research, adoption and barriers of DSTs, capacity building efforts under the grant project and application of geospatial soil data. While similar to the interview questions, the key informant interviews asked about respondent's opinions on sustainability, institutionalization of the work, what could have been done differently or better, and any unexpected outcomes,

Profiling questions helped determine which grant the respondent was associated with, the type of organization they worked for and their role, as well as the number of years they worked with the grantee, and the country they were primarily based in. We sent a link to the online survey via email to all respondents, using the online platform SurveyGizmo. Following the submission of the initial invitation, we sent out two reminders to increase the response rate and responses were monitored while the survey was live to ensure quality of data.

With 114 completed surveys out of 145 surveys submitted, the response rate for the online survey was 78%. The table below shows summary statistics of the online survey, including the percentage of the sample made up of each grantee and type of respondent, with the number of responses for each category.

Table A2. Summary statistics online survey

Grant respondent		
ACAI	34	(29.8%)
CSISA (Phase 2 and Phase 3 combined)	21	(18.4%)
N2Africa (Phase 1 and Phase 2 combined)	21	(18.4%)
SBPEA	21	(18.4%)
TAMASA	17	(14.9%)
Type of organization		
Academic partner	13	(11.4%)
Government sector partner	33	(28.9%)
Lead prime/implementing grantee	30	(26.3%)
Non-profit sector partner	21	(18.4%)
Private sector partner	14	(12.2%)
Other	3	(2.6%)

We used Stata and Excel to produce descriptive analysis of the quantitative survey data and NVivo to analyze responses to the open-ended questions. Quantitative survey responses were pooled across grant projects to generate overall results, and disaggregated by grant and other respondent characteristics where useful to gain additional insights.

M&E Data and Methods:

See following Appendix A1 for detailed description of methods. The M&E data warrant their own Appendix due to the level of detail we provide in the methods.

A1:Monitoring and Evaluation (M&E) Data

Introduction

This appendix presents a review across the five grantees of their M&E data reporting and processes. This appendix presents a systematic review and extraction of data from each of the grantees' results trackers; the first section of the appendix provides details on the methods for this systematic review. We discuss the results and present recommendations from this systematic review in the third section. The in-depth interviews collected limited data on the M&E process; we present results from the in-depth interviews in the fourth section. The appendix closes with lessons learned.

Systematic Review of M&E Methodology

Objective of the M&E Review

The purpose of the review is to determine what information the M&E data included and did not include about the respective programs. Secondarily, we used the review to identify strengths and gaps in the metrics collected to help the foundation develop better data collection platforms.

Available M&E Data

The M&E data analyzed across the five different grantees come primarily from standardized Excel documents titled "[Project Name] - Results Framework." There exists, of course, ample data outside of these Excel files – from project reports, impact evaluations, and in some cases supplementary data on individual project websites. However, to ensure that the M&E review does not repeat the desk review, the study team focused on the quantitative metrics collected and reported consistently in the Results Framework Excel documents.

Within each Results Framework Excel file, there are three tabs:

- **Before You Begin:** Consists of instructions on how to fill in the Results Framework and Results Tracker, and links to "Terms and Definitions" and a "Guidance Note" that gives readers a generic overview for crafting a Theory of Change and Results Framework.
- **Results Framework:** Allows foundation grantees to enter their project's Theory of Change into the Excel template. This tab is macro-enabled, to prevent target users from accidentally changing or tampering with the sheet, while maintaining the logical connection between goals, outcomes, outputs and activities.
- **Results Tracker:** Stores the M&E data (mainly in the form of bullet-point notes) from the grantee on the status of each objective listed in the Results Framework tab. Each row represents the Outcome/Outputs of the project identified in the previous tab. Each row has additional columns that allow grantees to specify the indicator and data sources required to validate that outcome or output. Columns represent different years of the project, so that grantees can enter their progress notes for each year of the project. Each year contains data on the initially planned "Target" for that year, the "Actual" result achieved, and finally a "Variance" column that shows the percentage difference between the actual and target.

The Results Tracker tab contains all of the data relevant to this review, largely consisting of bulleted lists and progress notes for each Outcome/Output.

M&E Methodology

While grantees fortunately used a single standardized template to store M&E data, the template did not store the data within cells that allowed easy computational analysis. As an example, cell AL25 in the CSISA III Results framework reads as follows:

- Five types of on-farm verification trials in India were conducted at 296 sites across 14 districts to assess promising directly seeded rice production practices, mostly around weed management & irrigation scheduling. Similar trials were conducted at 31 locations in 5 terai districts of Nepal.
- Targeting exercise identified 12 promising districts (6 in Eastern Uttar Pradesh, 4 in Bihar & 2 in Odisha) in India based on consistency in yield & availability of seed drills. In Bangladesh, 4 districts in FtF zone targeted where directly seeded rice covered 200 ha through service provision.
- 369 service providers (140 in Bihar, 170 in Eastern Uttar Pradesh & 59 in Odisha) in India and 85 in Nepal were trained and received technical support that enabled them service 4,793 ha and 450 ha in India & Nepal, respectively.

Each project's Results Framework generally had a "block of text" similar to the one above for each of the Outcome/Outputs within the entire project, multiplied by the number of years of that project. While an individual block of text is easy for a human to read, and allowed direct transfer of text to and from project reports, textual data make it difficult to assess overall patterns or trends within the data.

Data stored in this "block of text" format are difficult for a computer to parse and analyze. For instance, the text in the example above does not lend itself to presentation in a chart or graph format for visual analysis, and it is not possible to apply a summation or subtraction function to that cell as-is.

The study team's solution was to transform the data into a format easier to work with and analyze. The team did this through a few steps:

1. **Simplifying or categorizing:** Because computers have a difficult time parsing entire blocks of text, we simplified the text of an individual cell into a single category. Quantitative analyses commonly do this, especially when looking for commonalities across different free-answer responses to the same question. For this exercise, the study team chose categories of outputs or outcomes common across the different programs. For instance, all grantees had an output focused generically around "number of field trials conducted." Programs also had outputs focused around things like "number of people trained" or "number of partnerships formed."

   The study team then read each block of text, and assigned a particular block of text to a specific outcome/input category. In the example "block of text" above, we categorized the first bullet point under "number of field trials," and we categorized the third bullet point under "number of people trained." See the next sub-section below for a list of all the categories the study team devised, along with the reasoning for what types of activities or outcomes would fall into each category.

2. "**Atomizing" data:** The study team also broke a specific cell of text into multiple cells, with each new cell containing a discrete Outcome or Output within a specific country.

For instance, in the example "block of text" above, we transformed the one cell into several cells, since that single block of text includes outputs about field trials and trainings from India, Nepal and Bangladesh.

3. **Converting wide data to long:** Lastly, computers analyze data in long format, so we transformed an Outcome or Output with data for five years (i.e., five columns) into five different rows in a single column (i.e., one row for each year), and created an extra column specifying which year the data in each row pertains to.

Taken altogether, the study team transferred the block of text in the example above into the following form:

Table A3. Transferred Block of M&E Text

Project	Period	Country	Value Chain	Gender	OUTCOME	ACTUAL	TARGET
CSISA 3	2	India	Rice		# Trials	14	
CSISA 3	2	Nepal	Rice		# Trials	5	
CSISA 3	2	India	Rice		# Trained (Intermediary)	369	
CSISA 3	2	Nepal	Rice		# Trained (Intermediary)	89	

The study team manually went through each cell using a spreadsheet and applied the same transformation across the five grantees. In this way, the team created a single database, with data from all five programs contained in a single file with common metrics.

One important note is that as we did this, we purposefully skipped items related to internal management – in essence, items we considered "project updates" rather than outputs or achievements. For instance, we did not record cells that read "created internal documents for research procedure" or "successfully hired staff to input data." Even though these milestones are useful for internal monitoring of project processes (and some M&E systems use these types of metrics), the team wanted to focus on the benefits that a project created externally to best address the evaluation questions.

Categorization of M&E Data

The study team developed categories for the M&E data to create the database and generate M&E graphs and M&E findings. As noted above, we did not include categories representing project updates.

The definitions of these categories are as follows:

- **# Trials:** Broadly, this category includes the "number of research initiatives undertaken." This category includes field trials of seeds or agricultural inputs, and also data gathering activities such as household surveys or attempts to acquire data via satellite imagery or mapping. We counted field trials as distinct if they occurred in different districts or pertained to different crop types. For instance, a trial of a single crop done across 31 different farm locations within a single district would count as one trial, rather than 31 trials.
- **# Publications:** We counted peer-reviewed journal publications.

- **# Discoveries**: Discoveries are discrete and important agronomic research findings. For example, "We discovered that this strain of inoculant was the most effective one tested, and improved yield by 1 ton/hectare in trial locations."
- **# of Tools Created**: We defined tools as "any deliverable the project created that can help people outside of the project." This includes decision support tools, and also GIS maps created, databases, field manuals, online surveys and training videos.
- **Sum of Tool Target Users:** Number of people using a tool. This generally applied only to decision support tools.
- **# Trained (Researcher):** Number of Master's degree level or PhD level agronomic researchers receiving some kind of training.
- **# Trained (Intermediary):** Number of extension agents or other intermediaries receiving training. This would typically be training in a new method, or training on using a decision support application.
- **# Trained (Smallholder):** Number of farmers receiving training. This would typically be training in a new method, or training on using a decision support application.
- **Policy Change:** Any time a project activity supplied evidence for, or participated in, a process resulting in a change to a local law or piece of legislation.
- **# Partnerships:** Number of partnerships created by the project. For a partnership to count, it must be a formal, signed agreement (not simply "we worked with organization xxx").
- **# Workshops:** Any formal meeting between the project and a local community organization, a government agency or a private sector partner.
- **Public Outreach:** Number of people exposed to new information, or alternatively, number of leaflets or pamphlets created (the assumption being that all leaflets were eventually distributed). Note that this is a low-level output, as exposure to a leaflet does not necessarily imply a change in knowledge, skills and attitudes. (No indicators are collected related to knowledge, skills or attitude changes.)
- **Publicity Event:** Any program-held publicity event.
- **Hectares Impacted.** The area of land changed in some way.
- **Primary Reach:** The number of beneficiaries that a program reached.
- **Secondary Reach:** The number of people a project reached via intermediaries (usually an estimated number).
- **MTs Facilitated:** Metric tons of goods facilitated. This could mean that the project helped sell a certain amount of crop, or helped deliver or bring to market a certain amount of fertilizer or inoculant.
- **Value Created:** The dollar amount of value created (usually, a grantee estimate).
- **Missed Target:** Any cell where the grantee pointed out a missed goal.
- **Companies Created:** The number of program-created new businesses.

Within these categories and with the data available, we could not assess the "quality" of an outcome. For instance, we could record both a field test on five farms and a field test on 1,000 farms as one field test. As another example, a "partnership" could be a collaboration with a local community-based organization or with a large national-level agency. Therefore, direct comparison of data across, or even within, grant projects is likely to misconstrue the efforts of the program. A more robust M&E system along with better project data would allow this level of detail in the data.

Improving the M&E Process

The study team used a manual process to review the M&E data; a properly designed M&E system would more easily, or automatically, allow this type of review. For example, a system that instructed grantees from the beginning to break down their "blocks of text" into discrete outputs in different rows/cells would allow quick analyses across grantees to help identify common lessons learned, bottlenecks, etc. Additionally, the current Results Framework template already contains macros; a better template would have included macros to quickly consolidate any data inputted into numerical tables, dashboards, or other visualizations. In this section we review the findings from the M&E systematic review and make recommendations to improve M&E systems.

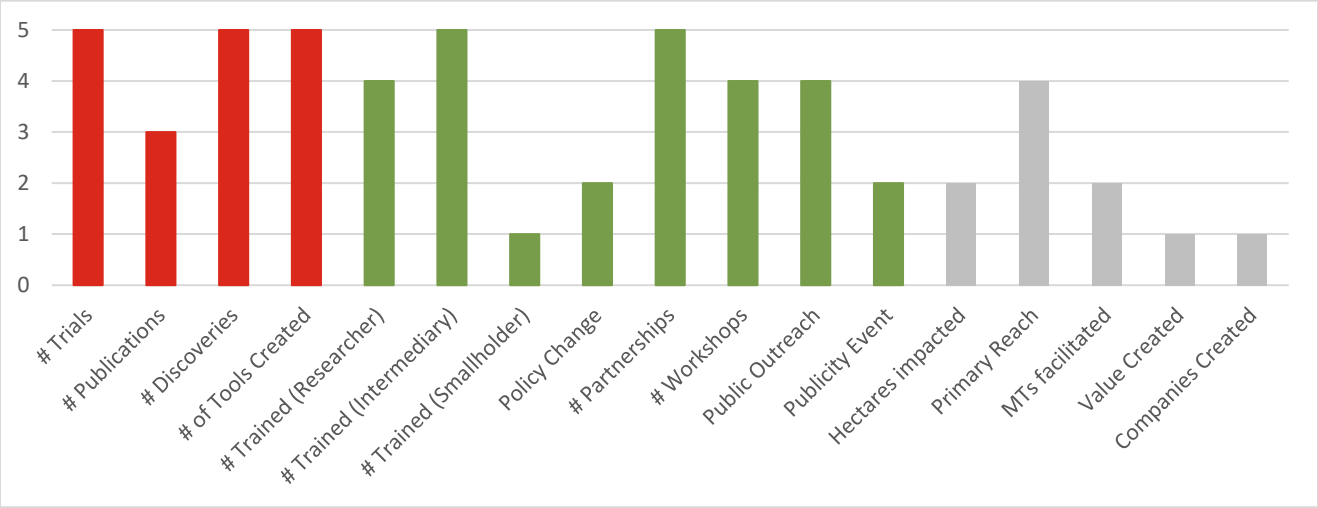
Quality of M&E Data

The current state of the M&E data for these grant projects does allow us to make broad generalizations on the outputs of each project, and where they failed to fully meet objectives, or missed targets entirely. However, the data also contain limitations that prevent deeper comparisons across projects.

Lack of Consistency Between Projects on Type of Data to Collect

Given the diversity of grantees, we expect some customization of indicators, but grantees did not use any common set of indicators (Figure A1), which made comparability across grant projects difficult. Manually going through the Results Frameworks and categorizing each output into common groupings partially addressed this issue; however, we found these categorizations less successful for the impact-focused indicators. For instance, some grantees showed their impact in hectares of land impacted, while other grantees showed their impact in terms of beneficiaries reached. This makes numerical comparisons between projects impossible, and prevents the calculation of useful metrics such as "benefit gained per dollar spent."

Figure A1. Projects that included stated data type



Lack of Explanation of Data

There often was no explanation concerning the calculation of numbers. The Results Frameworks file did have a column titled "Data Sources," but this usually lacked precise details. Many M&E operations make use of detailed Indicator Reference Sheets, where every single indicator has an in-depth description of the definition of that indicator, the source of information for the data, and the formula used to calculate the indicator, and caveats for the interpretation of the indicator.

Lack of Consistency in the Specificity of Data

Even when grantees used the same or similar indicators, differences in the level of specificity prevented easy comparisons. For example, some grantees reported how many training *events* they held, while others reported how many *people* they trained.

Limited Data Capture for Downstream Impacts

M&E data did not report downstream impacts; this finding is consistent with findings from the desk research. While grantees did a good job of reporting on lower-level outputs such as tools created or number of people trained (even if the way this data was reported was inconsistent), there was very little data to show, for example, that these outputs were well received by beneficiaries, were simple to use, led to concrete behavior changes in beneficiaries, or led to improvements in crop yields or the livelihoods of farmers. Though these data are not as straightforward to capture, they are important in identifying whether a project achieved the positive change laid out in the theory of change. We provide suggestions on how to capture these in the Suggestions sub-section below.

Geographic Information Not Well Captured

Failure to capture downstream impacts made it difficult to show results for individual countries, or disaggregate results by country within a project. Of the different results trackers, only the one for CSISA had a column for country. Additionally, grantees often recorded outputs as aggregates across the entire project, rather than disaggregating the figures specifically by country.

Data on M&E Tracker Updated Annually Only

Rather than including specific dates for various events or achievements, grantees updated data on the M&E tracker only annually. If grantees were to record events as they happened (e.g., recording that a training for 50 people happened on January 1, 2020), M&E data would reflect progress as it happens, and would also produce more-granular charts of a particular output over time. In addition, some

grantees reported figures cumulatively for the entire project, whereas other grantees reported only outputs for a particular annual period. We recommend that data housed in a database cover that specific time frame, rather than be cumulative.

Recommendations to Improve M&E of Grantees

Although grantees succeeded in capturing data about basic research outputs, there were gaps in data collection. As mentioned above, these include inconsistencies in indicators used, and lack of data on downstream impacts (such as data on tool use, agronomic impact, and ensuring sustainability of the outcomes past the life of the grant project). Better data collection might have improved project outcomes both at the output and impact levels. Some steps to improve M&E data include:

Create Common Indicators Across Projects

Thematically, the types of data collected across grantees were consistent – these included data on field trials, tool development, trainings, dissemination, partnerships, and beneficiaries. The specific data collected differed (e.g., people trained vs. number of trainings), making it impossible to compare certain figures across projects. Being able to do that would give the foundation greater visibility on key metrics, and give grantees themselves a useful point of comparison to see how they are doing relative to other projects.

Develop Specific Protocols or Procedures for Collecting and Calculating Indicators

Data on outputs such as number of people trained or number of tools developed are easy to measure. Projects can determine these numbers from internal reports, and the calculation is not complex. This may be one of the reasons that these output-level data were more available across the grantees than other types of data. Impact metrics present more ambiguity about what is important to measure and how to measure it in a cost-efficient and meaningful way. Some projects used "number of beneficiaries," while others used "hectares of land impacted." In such cases, developing specific indicators and in-depth Indicator Reference Sheets could help grantees formalize their impact metrics.

Put Greater Focus on "Difficult to Measure" Impact Indicators

Grantees were lacking data to adequately answer the following types of questions:

- Did providing training actually lead to an improvement in the skills or knowledge of the participants?
- Did people exposed to publicity about an agronomic solution end up using the solution?
- Did people who ended up using DSTs find them useful and easy to use?
- Did adopting these new behaviors lead to increases in productivity?

Although these questions are more difficult to answer than output-level indicators, they are important in assessing whether a grant project actually caused positive agronomic impacts.

Devising indicators to answer these questions is possible with limited resources. For example, a quick paper-based baseline and end-line knowledge assessment would have been useful in answering the first question. This would accompany an indicator phrased as "number of trainees who now understand zero tilling." A brief one- or two-question short message service survey sent to farmers that used a decision support tool could help answer the third question above.

There are ways to assess productivity increases as well; the CSISA grantee used satellite imagery to detect how many hectares of land were planted with early sown wheat. Grantees should consider

other secondary data sources that collect aggregate information on crop production (e.g., from Ministry of Agriculture farm surveys), if these are available.

Tying Funding to the Achievement of more-Downstream Milestones

Tying funding to downstream milestones (number of beneficiaries, hectares transformed, etc.) would give grantees a greater impetus to focus on those later milestones.

Incorporate Legacy Objectives

Often, grantees did not include objectives about sustainability of outcomes. From the project's inception, including objectives about the legacy of the project would allow managers to prepare a plan to ensure the tools they develop remain useful after a grant project ends.

Suggestions for M&E System

Despite obvious efforts to create a common M&E data collection system (all the Results Frameworks across the grantees used the same template), lack of guidance on how to fill out the template – particularly on using common indicators and common procedures for data collection – hindered comparability across projects and impeded overall data quality. While the above suggestions relate to the M&E Framework for the foundation agronomy grant projects as a whole, below we provide suggestions to improve the Results Framework Excel file, or, more broadly, any platform designed to store M&E data across different grant projects.

The primary challenge with the Results Framework Excel files is that, as previously mentioned, the data storage method makes it impossible to perform quick analyses of the data within or across programs, and hinders visualization of the data. This goes against the cornerstone M&E goal of being able to assess what is happening in a particular intervention, and using that knowledge to refine project implementation. What is especially unfortunate is that it appears (based on the amount of text entered into each sheet) that each grantee spent substantial time modifying and updating their results framework files. Even though these sheets included macros, there were no macros to enable a grant project manager to quickly aggregate all the quantitative findings across projects. Small changes to the Excel templates and proper explanation of correct usage could make a large difference in data quality, with minimal extra time spent on the grantee side.

Following are a few ways the foundation could create a better system for storing M&E data for the future.

Excel-Based

The first and lowest-cost solution would be for each grantee to use an Excel file similar to the Results Framework but which included from the beginning the structures needed to easily store data for quick analysis.

Web Form-Based

Another way to handle the collection of data across different grantees would be to use an open-source survey collection tool such as Organizational Network Analysis (ONA) or Open Data Kit (ODK) (incidentally used by the majority of Gates Agronomy grantees) as a way for grantees to report indicators.

Platform-Based

Lastly, depending on the level of depth and detail required for the M&E data, the foundation could commission the creation of a proprietary M&E platform. This common platform or shared M&E data portal would essentially be similar to the web form-based system described above, but with more features, customization, and data dashboards for various aspects of the project. These

dashboards would be immensely useful in terms of taking a "pulse" of each of the grantees in real time and quickly being able to see results across projects as they come in.

The three above solutions all use database structures that are more defined than the current structure of the Results Framework. The three solutions above would likely not add much more time burden on the grantee side, and the foundation can select a level of complexity based on the foundation's needs and budget.

Results from the In-depth Interviews about M&E and M&E Systems

Only eight respondents addressed M&E across the five grant projects in any detail. Of these eight, five mentioned the Results Tracker or Results Framework, while five mentioned M&E as being based on field visits or feedback from stakeholders (two respondents mentioned both).

Respondents that discussed the Results Framework mentioned that it was "well organized," served to facilitate discussion with the foundation staff, and facilitated project reporting.

> *But there is a result tracker system, which we internally assess ourselves against, and then we have pretty frequent, at least once in a quarter, if not more, interactions with the program officers from the foundation side. […] If there are any changes that we want to make, add some new action items etc., we get approval. We propose something if it's interesting or exciting and then we get approval.*
>
> - CSISA staff

However, two respondents reported that the M&E system was not viewed as useful.

> *M&E was never taken […] seriously – happens during project formulation and then something [that] needs to be done.*
>
> - [Anonymized]

However, admittedly based on a small sample, an equal number of respondents talked about M&E in the context of soliciting feedback from stakeholders or target users. When respondents mentioned this method, they talked about using field visits, meetings, or stakeholder evaluations to determine whether or not research was proceeding well, assess what was being learned, and determine whether or not solutions were meeting stakeholders' needs.

> *[W]e would have these periodic conversations and workshops and looking at what we've done, and where we are, and what do we need to change, and our yearly planning meeting were really based on what happened the prior year, and the monitoring happened throughout the year, it wasn't just a one-step process. But it did help in determining the direction and the changes in our planning.*
>
> - TAMASA staff

Lessons Learned for M&E

The main report provides our general findings and recommendations for M&E associated with agronomy research grant projects.

Appendix B: Grant Summaries

Grant Projects

We organized each of the Appendix chapters summarizing data collected from the grantees (Appendix B1 through Appendix B5) in alignment with both the Agronomy Grants Framework developed for this evaluation and the structure of the chapters of the main report. Each grantee summary is divided into six sections:

1. **Introduction**: Broad description of the activities of the grant project. This section is based primarily on the document review described in Appendix A.
2. **Needs Assessment**: Describes how the grantees identified agronomy research needs, the target users of the research, and how they prioritized the agronomy research needs.
3. **Development**: Describes the efforts to improve the capacity of local stakeholders to undertake research and development, research undertaken, and any tailored agronomy solutions developed.
4. **Scaling**: Describes grantees' approach to scaling agronomy solutions, including dissemination of ideas and building the capacity of local stakeholders and institutions to scale or disseminate agronomy solutions.
5. **Policy Development, Institutionalization, and Sustainability**: Describes grantees' approach to ensuring longer-term adoption of their research, agronomy solutions, and tools, including plans to institutionalize their work through local stakeholders and institutions.
6. **Impact**: Describes farmers' uptake of grantee-developed agronomy solutions, increased productivity by farmers, and any strengthening of supply chains.

We divide sections 2 through 6 above to present results according to the source of the data:

a) **Document review**: We present items found when reviewing grant project documents related to the subject of each sub-section.

b) **Results tracking data:** Each of the grantees developed a monitoring plan to track activity performance and monitor progress against outcome targets. Analysis of the monitoring data aims to show the extent to which grantees achieved their target outcomes, which is indicative of the impact they were able to make, and demonstrates which aspects of the grant project were most challenging.

The monitoring plan included a Results Framework (RF) with primary outcome targets, intermediate outcome targets, output targets, and a Results Tracker (RT), which detailed progress made towards these outcomes targets over time. Grantees developed the RF at the start of the grant project, and mapped how the grantee aimed to meet its primary outcome targets (targets for long-term objectives) by linking these to intermediate outcome targets (targets for shorter-term objectives, which, if achieved, will lead to the desired primary outcome targets), and output targets (targets to track implementation of activities and/or initial expected changes in the target population after activities are implemented). For each of the intermediate outcome or output targets in the RF, the RT reports on achievements against yearly targets/milestones. The RT of grant projects that ended mostly summarizes the final results for each of their targets.

The number and definition of targets for each grant project differed, limiting comparability across grantees. Grantees self-reported on their achievements against targets/milestones, drawing on their administrative data. Some grantees also used data from evaluations they commissioned. N2Africa, for example, conducted an impact evaluation during its second phase, which provided more detail on its achievement of its targets. TAMASA, ACAI, and SPBEA commissioned a survey to obtain additional evidence on adoption and use of their (digital) technologies. Availability of details on achievements at the outcome or output target levels varied. Not all grantees provide details on progress made at the primary or intermediate target outcome levels. Most, however, summarize progress on all output targets in the RF, but CSISA Phase III does not, and N2Africa Phase II reports on a selection of its output targets.

To determine the extent to which grantees met their targets, we use each grantee's most recent RFs and RTs. For grant projects that have ended (CSISA Phase II, N2Africa Phase I and II, TAMASA) we report on the grant project's final results for each target.[10] For grant projects that are still ongoing (ACAI, CSISA Phase III), or have recently closed but where no data on the latest years is available yet (SBPEA), we report a description of achievements on each target in the last year for which monitoring data is available.[11] While this does not provide a full picture of how the grant project is achieving targets, it is indicative of how well the grant project is progressing toward these.

Not all targets were specific or measurable. Generally, primary and intermediate outcome level targets were less well defined than output targets, which were more often quantifiable. For targets that lacked specificity and that were not quantifiable, we relied on the grantee's qualitative self-assessment describing whether they had reached their target or not. The grantees' self-assessment, however, was not always sufficient to determine whether or not the grantee had achieved the targets. In these cases we could not establish whether targets were met.

We report on targets and achievements as follows. For each grant project, we include a table with the rows listing primary outcome targets (in bold) and the underlying intermediate outcome targets, with the same numbering as reported in the RT. The columns show the extent to which targets were met. The last column displays the total number of targets associated with each primary outcome target. We use the following classification to report on the extent to which outcomes and targets were met:

Target exceeded: The grant project achieved a greater amount or number than the target specified (e.g., the grant project set a target to reach 1,000 farmer households but was able to reach 1,500 farmer households).

Target met: The grant project met its specified target activities or target amounts or numbers (e.g., the grant project set a target to publish two documents that were papers and/or reports, and published two papers).

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[10] For N2Africa Phase I, however, no RF appeared to be available. The grant provided a narrative showing how it had progressed against targets, but since these targets were not quantified and there is no similar way to report on targets as for the other grants, N2Africa Phase I is not included in these data.

[11] The most recent monitoring data for ACAI is from December 2019; for CSISA Phase III the data is from November 2019; and for SBPEA the data is from June 2019.

Target not met: The grantee was not able to undertake all target activities, or was not able to reach the target amounts or numbers (e.g., the grantee aimed to institutionalize a tool but was not able to find a host institute).

Target/actual lacks clarity: The grantee did not clearly define the target, and/or the actual description of achievements lacked sufficient detail to assess whether the target was met or not (e.g., the grantee sets the target to develop methods to "collect and analyze spatial yield data and agronomy data," but does not further specify the type of methods, while the actual states that "crop mapping and yield assessment systems in Google Earth Engine developed for Nigeria").

Target/actual missing: The grantee does not provide any details on the actual, and/or in the case of ongoing grant projects, a yearly target/milestone is missing (e.g., the grantee sets the target to "identify pathways towards an enabling environment for maize productivity," but no actual is given).

We report these tables in the Impact sub-section of each chapter, but refer to the indicators in the RT throughout each chapter.

We emphasize that for grant projects that have not ended, we report on the status of progress towards targets using the last year for which data is available. Thus, a grantee may still be progressing towards its target, although the most recent monitoring data from the year we use shows that the target was not met. We also note that in applying this classification, we do not scrutinize or question the monitoring data.

c) **In-depth interview results**: In this section, we present results from the qualitative, in-depth interviews conducted with grantees and stakeholders. In addition to presenting the "what" (e.g., was done), this section focuses on "how" and "why" things were done, and provides greater context for interpreting the results in the first two sections.

Note that the in-depth interviews focused on the use cases that the grantees selected for this evaluation. Responses to the in-depth interviews were not limited to these use cases, but interviewers would often use the use cases to prompt for examples and in-depth exploration.

The use cases for each grant project are:

N2Africa (focus on Ethiopia)

Inoculants: Inoculant technology was a main focus for N2Africa, to demonstrate how inoculants can improve yield and to increase the use of inoculants.

Women's Empowerment: A major component of N2Africa's Phase II work was integrating women into all aspects of the project, from field demonstrations to students supported to beneficiaries of technologies.

CSISA (focus on India)

Early Sown Wheat: Changing temperatures threaten wheat production in India, where high temperatures can dwarf wheat production (at times up to 50%). To address this, CSISA conducted research on sowing (planting) wheat earlier than the government-recommended planting dates.

Zero Tillage: "Tillage" refers to the preparation of land for planting, such as burning refuse, plowing soils, or disposing of weeds. "Zero tillage" is a system popular in conservation agriculture that prioritizes minimal disturbance of soils in the time between harvest and planting.

SBPEA (focus on Uganda)

Integrated Soil Fertility and Pest Management: This was applied following a multi-step intensification pathway. The key objective was to maximize the synergies between the practices and minimize the trade-offs, which varied across sites and even farmers within a given site.

Residue Management for Weevil Control: Although corm removal is part of residue management and is integrated with other practices under Integrated Soil Fertility and Pest Management, it came out prominently in this use case, specifically for destroying the breeding sites of banana weevils—a key banana pest.

TAMASA (focus on Ethiopia)

Nutrient Expert Tool for Contextualized Fertilizer Recommendations: TAMASA's prioritized use case is a tool called Nutrient Expert. Nutrient Expert is an Android or computer-based program that provides site-specific fertilizer recommendations based on specifics about soil and crops grown on a specific plot of land.

Development of Apps: In addition to the Nutrient Expert tool, TAMASA developed two apps to help farmers select the best maize for their circumstances and ensure farmers plan efficiently for plant density. The two apps are the Maize Variety Selector and Maize Seed Area.

ACAI (focus on Nigeria)

ACAI initially identified use cases around demand for specific cassava agronomy recommendations formulated by the different partners. These included fertilizer blending, fertilizer recommendations, best planting practices, intercropping, scheduled planting, starch content, and, later on, weed control. ACAI's use cases for the case study focus on an "agronomy package" that includes these recommendations.

d) **Online survey results**: Presents the results of the online survey with additional Grant Project Stakeholders. These results both reinforce findings from the previous section and provide some insight into the views of stakeholders on the issues.

e) **Lessons learned**: This section draws on the four data sources above to summarize what the grantees learned about each topic of the sub-section.

B1: CSISA Summary

This chapter summarizes the data collected for the CSISA grant projects (Phase II and Phase III), and, based on the data collected, provides lessons learned from the CSISA grant projects' implementation. The chapter starts with a brief description of the grant project. Sections reflecting different parts of the Agronomy Grants Framework follow (the chapters of the main report body also follow this structure). For each of these sections, we present the data from up to four different sources (document review, review of the results trackers, in-depth interviews with grantees and stakeholders, and the online survey with grantee stakeholders; not all data sources are available for all parts of the framework). Each section concludes with a sub-section on lessons learned. The introduction to the appendices provides definitions and content for each of the sections of this chapter.

List of Acronyms

ATARI	Agricultural Technology Application and Research Institutes (India)
BADC	Bangladesh Agricultural Development Corporation
BAMETI	Bihar Agriculture Management & Extension Training Institute
BARI	Bangladesh Agricultural Research Institute
BMGF	Bill and Melinda Gates Foundation
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
DOA	Departments of Agriculture
DSR	Direct seeded rice
EIGP	Eastern Indo-Gangetic Plains
EUP	Eastern Uttar Pradesh
IASRI	Indian Agricultural Statistics Research Institute
ICAR	Indian Council of Agricultural Research
IFPRI	International Food Policy Research Institute
IGP	Indo-Gangetic Plains
IRRI	International Rice Research Institute
KVK	Krishi Vigyan Kendra (agricultural extension)
LDS	Landscape Diagnostic Survey
NARC	Nepal Agricultural Research Council
NARES	National agricultural research and extension system
PAD	Precision Agriculture for Development
PTR	Puddled transplanted rice
RWCM	Rice-Wheat Crop Manager
SI	Sustainable intensification
UP	Uttar Pradesh
USAID	US Agency for International Development
ZT	Zero tillage

Narrative Description of Cereal Systems Initiative for South Asia (CSISA) Activities

CSISA (2008-2020) seeks to address yield constraints across three cereal systems – rice, maize, and wheat – in three countries: Bangladesh, India and Nepal. The foundation chose these countries because of their high rates of poverty, food insecurity, and yield gaps. A variety of historical, climatic, ecological and economic factors affect all of these issues. Thus, CSISA takes a multi-faceted approach to address a multitude of constraints. CSISA self-identifies as working within the "messy middle" with a variety of public and private sector partners, working across scale and value chains. Rather than intervene simply at the farm level, CSISA works with intermediaries such as service providers, NGOs, agricultural extension agents, agricultural research institutes, and government bodies, anticipating that such actors are well poised to scale interventions.

This report focuses only on Phases II and III. In India, the project focused on the states of Bihar, Odisha, and Eastern Uttar Pradesh (EUP). The U.S. Agency for International Development co-funded CSISA except as noted below.

Phase I (November 2008–July 2012)[12]

The International Rice Research Institute (IRRI) implemented the first phase of the project ($22.5mil). Activities included:

- Identification of technologies and rice, maize and wheat varieties that can handle climatic stresses (such as heat and insects), including directly seeded rice (DSR), zero tillage (ZT) machines, and hybrid seeds
- Participatory research with farmers in India to assess technologies (like ZT machines), crop management scenarios (experimenting with different crop combinations), and livestock integration
- Creating the CSISA Knowledge Bank, an online dataset that hosted documents on "best-bet" technologies.

Phase II (September 2012–June 2016)

CIMMYT assumed the lead implementation role in Phase II ($18.6mil). The main activities included:

Timely crop establishment: The most prioritized case regarding timely crop establishment was early sown wheat, especially so for India. In India, wheat is planted in the late fall and harvested in the springtime. However, rising spring temperatures – otherwise known as heat stress – are dwarfing wheat growth. CSISA developed a hypothesis that planting wheat earlier than the government-recommended date of November 15 would allow the crop to mature before temperatures begin to warm in the springtime. Field trials conducted in collaboration with Krishi Vigyan Kendras (KVKs; extension agencies) in the states of Bihar and Uttar Pradesh confirmed CSISA's hypothesis, and they distributed their findings to the state-level departments of agriculture (DOAs), the Indian Council of Agricultural Research (ICAR), and the Agricultural

[12] Pakistan was included in Phase I but not the subsequent phases.

Technology Management agency. In 2013, the state of Bihar officially adopted CSISA's findings and revised their recommendations for wheat sowing to early November.

Resource-conserving crop establishment and land preparation: The family of technologies for this use case include ZT, DSR, and the app Crop Manager. "Zero tillage" is a system that prioritizes minimal disturbance of soils in the time between harvest and planting. In a zero tillage system, crop residue left over from harvest remains on the fields, providing cover and nutrients for soil. Then, at the time of planting, drills attached to tractors cut through soil or crop cover and directly plant seeds and fertilizers. While zero tillage can help conserve soil nutrients, it also requires most farmers to hire a seed drill/tractor operator, and therefore is potentially an added cost of production. CSISA has promoted zero tillage with wheat farmers and service providers (SPs), who they hope will scale ZT operations.

CSISA also promoted DSR. Conventional planting of rice requires farmers to first plant and raise seeds in a nursery before the farmers transplant the seedlings into a puddled (wet and ploughed) field. DSR takes the nursery out of the equation, and instead allows farmers to sow "seeds directly into the main field with a seed drill rather than transplanting of seedlings."[13] As with ZT, CSISA promotes DSR with both farmers and service providers.

Finally, CSISA collaborated with IRRI to develop a software decision-making tool (web- and Android-based) that helps farmers determine the best fertilizer to use for their rice, wheat or maize crops based on field considerations including location, size, and seed variety. CSISA rolled out the tool, named Crop Manager, in the states of Bihar and Uttar Pradesh (UP) in India, and in Bangladesh. In 129 on-farm trials in eastern UP Bihar, the use of Crop Manager "increased rice yields ... by .5 t/ha compared to current farmers' practice" (Final Narrative, pg. 9).

Phase III (November 2015–November 2020)

The Bill and Melinda Gates Foundation funded the India component of phase III ($18 mil implemented by CIMMYT), while USAID funded work in Bangladesh and Nepal. The main activities from India include:

In Phase III, CSISA continued research into and promotion of **early sown wheat**. Much of the research effort focused on Landscape Diagnostic Survey (LDS) research in collaboration with KVK (see below), and results confirmed findings from Phase II: that wheat sown in early November yields better than wheat sown in late November or December. However, CSISA noted a number of challenges to potential scalability. The first pertains to the impact the early sowing of wheat has on rice. Many Indian farmers grow both rice and wheat on a single plot of land, referred to in CSISA literature as the rice wheat cropping system. Wheat is grown in the winter and spring months, and then fields are transformed to grow rice in the summer months. For many farmers, when rice is ready to harvest determines when they plant wheat (CSISA III_Narrative-31Dec19, pg. 14). Therefore, to plant wheat early, farmers must make changes to their rice production as well. To address these challenges, CSISA suggests the use of "medium-duration rice hybrids [that] save time in the cropping calendar while preserving yield potential" (2016 Progress Narrative, pg. 16).

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[13] A visual and step-by-step of how directly sown rice works can be found here: https://csisa.org/wp-content/uploads/sites/2/2014/06/English-DSR-1.pdf

Zero tillage (ZT): CSISA Phase III extended its targets for new and continuing land cultivated using zero tillage. Reports from 2019 are consistent with earlier Phase II reporting in showing high yields. While CSISA's research has shown ZT to help increase yields, the project has encountered a number of challenges, many of which surround the fact that ZT comes at a cost both for farmers hiring ZT services and for the providers supplying them.

Engaging the KVKs to conduct participatory science (research) and technology evaluations: KVKs act as middlemen between farmers and the Indian Council of Agricultural Research (ICAR). In 2016, CSISA and ICAR formalized an agreement to use the KVKs to conduct research (CSISA Phase III – Annual Report 2016, pg. 1). CSISA's theory of change was that if KVKs were able to produce demand-driven research and evaluations of their own, they would provide the Indian state with a built-in M&E system to assess where technologies were and weren't working, and identify context-specific interventions. "CSISA ... worked to raise the capacity of the KVK system with respect to participatory research methods, survey design, and digital data collection for landscape characterization" through trainings and exercises (2019 narrative, pg. 8). Perhaps the most significant project was the Landscape Diagnostic Survey (LDS), a household survey on rice and wheat production carried out over five states (Bihar, Chhattisgarh, Odisha, Uttar Pradesh, and West Bengal). KVK officers administered the LDS using digital technologies to collect, transmit and analyze data. CSISA hopes to institutionalize the LDS within ICAR and the KVKs to achieve the project's objective of building capacity for scientific research and evaluation.

Soil Intelligence Systems India (September 2018–February 2021)

Carried out in Andhra Pradesh, Bihar and Odisha, Soil Intelligence Systems India (SIS, $2.5mil, implemented by the International Maize and Wheat Improvement Center (CIMMYT)), is a spin-off from the main CSISA activities. SIS was a response to what officials saw as a trend of generalized fertilizer recommendations and interventions, such as India's Soil Health Card initiative, that relied on sampling farm soil for each individual farm or plot, which is time-consuming and expensive. SIS aims to develop detailed digital soil maps by combining existing soil data with new data derived from satellite imaging. SIS envisions that these maps will help provide precise recommendations for managing soil health management, including fertilizer type, water resources, land use planning, and commodity production. One of the existing datasets SIS is using is CSISA's LDS.

Needs and Demand

How CSISA identified agronomy research needs and the target users of the research, and how they prioritized the agronomy research needs.

Document Review

The program documents included the results of a prioritizing activity – the "ex ante analysis" – that occurred at the end of Phase II, but did not contain details about how CSISA undertook needs assessments (which likely took place during Phase I) or the exact methods used in the ex ante analysis. CSISA also undertook a household survey of farmers at the beginning of Phase II.

CSISA Phase II: Project documents indicate that CSISA Phase II sought to address multiple needs within national agronomic systems, which resulted in targeting multiple target users, including agri-business, government extension workers, farmers, input dealers, service providers, credit providers, and food security initiatives (Table B1).

Table B1. CSISA Phase II: Identified needs and target users

Need identified	Target user category
Yield gaps in key cereal crops: Slowed rice and wheat yield increases have corresponded with increased food costs.	Farmers, service providers, extension, input providers, agri-business
Increased accessibility of machine rental/hire: Some of CSISA's core interventions – mainly ZT and DSR – require machinery, which is too expensive for most farmers to purchase. To bridge this gap, CSISA aimed to support new and existing service providers in renting machinery to farmers on an as-needed basis.	Farmers, service providers
Training for extension officers on new trends in agronomy (improved varieties, planting methods, fertilizer management).	Extension, farmers
Best practices training and market linkages for maize value chain in Bangladesh, where the demand for maize is growing.	Farmers, service providers, input dealers, agri-business

CSISA Phase III: Phase III employed the hub concept, which "recognizes that innovation is not a single act but an amalgamation of linked activities that require coordination to ultimately achieve durable impact with farmers" (2015_CIMMYT_Proposal, pg. 6). CSISA's target users were again farmers, service providers, agro-dealers, extension officers and institutes (e.g., the KVK), research and agricultural institutes, and the private sector (Table B2).

Table B2. CSISA Phase III: Identified needs and target users

Need identified[14]	Target user category
Access to climate-efficient technologies	Farmers, service providers
Labor-saving technologies (e.g., mechanization)	Farmers, service providers
Knowledge of appropriate inputs and products	Farmers, agro-dealers, extension
Strengthened output markets	Farmers
Expansion of farmer access to extension and/or other avenues of agro-knowledge	Farmers, agro-dealers, extension
Increased capacity of research and extension organizations to assess and respond to farmers' needs in real-time	Extension, research and agricultural institutes
Knowledge of emerging markets	Private sector
Cooperation among organizations to synthesize research and development efforts	Research and agricultural institutes

In-Depth Interview Results

CSISA II built on the lessons learned from Phase I, and subsequently Phase III built on the lessons learned in Phase II. The selection of activities for Phase III was both formal and informal. At the end of Phase II, CSISA undertook the foundation-requested ex ante analysis. The ex ante analysis created a "priority index" of 10 core interventions based on set criteria, including:

- Potential profit per hectare (based on the gap between actual and potential yields)
- How many households would potentially benefit
- The importance of CSISA's role
- Whether or not other actors were doing similar things

[14] Needs adapted from list on 2015_CIMMYT_Proposal, pg. 7. We retained the ideas as expressed in the original documents, and thus there are differences in style between Table B1 and Table B2.

- Whether or not progress hinged on CSISA's activities
- The intensiveness of the investment activities
- Whether or not CSISA was training actors in the field, or master trainers

The aim of the prioritizing process was to identify the areas where CSISA has the best potential to make the largest impact. CSISA used the resulting "priority index" to determine how much budget different interventions would get. The CSISA staff that discussed the prioritization index process reported that they believed it was a rational and helpful process, although one respondent cautioned that future prioritization processes should be as inclusive of stakeholders as possible, to ensure various points of view are part of the priority-setting exercise.

However, while the "priority index" defined broad priorities, CSISA staff remained flexible in their work patterns and retained the ability to respond to stakeholders' needs, even if the request was not one of the priority activities.

> *[The government] banned farmers not to burn crop residues, but the farmers ask questions then, "What do I do with it?" [...] So CSISA and a few other projects have been trying new machines that can help incorporate the residue in the soil itself, and those, as of now, if you talk to policymakers, that's the only solution everyone is talking about.*
>
> – CSISA staff

When asked about the main targets of the research, most respondents listed farmers as the main target user. CSISA staff also emphasized that there were multiple stakeholders (as discussed above in the document review) that the research dissemination also included. However, CSISA intended its research to meet the needs of farmers. Inasmuch as the research helped other stakeholders, it was to enable the stakeholder to use the research to target farmers. For example, the LDS targeted the Technology Application and Research Institutes (India)(ATARIs), KVKs, and government in terms of who received training and helped to implement it. However, ultimately, the goal of the LDS is to provide data to the KVKs that can help inform them of the needs of farmers and thereby improve their capacity to fulfill their mission of advising farmers.

Online Survey Results

The responses to the online interview generally reflected the responses from CSISA staff, although many of the online respondents might not have been aware of the "priority index" itself. Seventy-five percent (15 of 20) of respondents reported that CSISA prioritized their research based on the needs of beneficiaries. The same proportion reported that CSISA prioritized research based on the expertise of the research team, and 60% (12 of 20) reported that CSISA prioritized their research based on interest from partners and on agronomic constraints. These answers appear to reflect the multiple inputs used in the ex ante analysis: that is, the analysis included as criteria related to the potential benefit to farmers the ability of CSISA to successfully enable the benefit, and some consideration of other partners' activities. Eighty-five percent (17 of 20) of online respondents responded that they thought CSISA had a good understanding of how to assess whether there was demand, indicating that selected stakeholders had a positive view of the overall process.

Respondents to the online survey were most likely to mention farmers and KVK (agricultural extension agents) as the main target users of CSISA's research. Thus, stakeholders' perceptions

of the main target users of CSISA's research were in line with project documents and staff understanding.

Main Lessons Learned on Needs Assessments and Demand for Research

CSISA was able to apply lessons learned about demand and research to other parts of the Agronomy Grants Framework. For example, while CSISA Phase II placed heavy emphasis on DSR, adoption remained low "due to the perceived risk of poor crop performance among farmers" (Results Tracker-31Dec19, AG/25). Therefore, CSISA shifted in Phase III to focus on training service providers and input dealers on DSR tools and associated herbicides, and evaluating practices that might reduce DSR-associated risks. Priority setting was a "demand-driven" exercise initially – reportedly based on multiple conversations with farmers in Phase I. The needs of farmers are manifold; focusing on not just the needs of farmers but on areas where the grant project is likely to have the largest impact required a priority setting exercise. The research still aimed to address the needs of farmers, or agencies helping farmers, even if the ex ante analysis was not fully "demand-driven" in the sense of including farmers themselves in the process. However, within the priorities established, CSISA retained flexibility in responding to stakeholders' needs, and was able to adapt to ongoing learning.

The ex ante analysis presented an innovative approach for CSISA. Without some sort of prioritization process, respondents thought that CSISA risked losing focus, becoming overly reactive, and not working with reference to a longer-term vision. However, prioritization processes like the ex ante analysis are not perfect, and the results provide guidance but not absolute rules. The ex ante analysis shows promise for replication, but further thought and research into how to optimize ex ante style analyses would also further strengthen the usefulness of these analyses.

Development

CSISA's efforts to improve the capacity of local stakeholders to undertake research and development, research undertaken, and tailored agronomy solutions developed.

Document Review

CSISA Phase II: Overall, Phase II focused on six areas of research: "development and inclusive deployment of improved cropping systems, resource-conserving management technologies, new cereal varieties and hybrids, livestock feeding strategies and feed value chains, progressive policies and strengthened markets" (Final Narrative, pg. 1). The project conducted research on the three target crops in all three countries (Table B3).

Table B3. CSISA Phase II country-level research activities

	Bangladesh	India	Nepal
Maize	Maize research focused on improving planting methods through the development of sowing and fertilization machinery and the development of a nutrient management decision tool.	Research focused on methods to optimize plant population and fertilizer application, and found that bed planting resulted in superior yields over flat planting. A study found that long-duration hybrid varieties usually out-yield short-duration varieties. As in Bangladesh, CSISA developed a nutrient management decision tool (though the details of the tool are unclear), which reportedly helped farmers increase yields 1.5 times. And finally, CSISA compared various weed management techniques to farmers' current practices. They found that highest yields were achieved by either the use of an herbicide combo or the application of Atrazine (herbicide) combined with mechanical weeding.	Maize research focused on planting methods and improved varieties. Research found that the use of sowing machinery versus manual sowing increased yields by 50% and cut planting costs by 50%. CSISA identified a geographic gap in availability: previously all hybrid maize seeds were available only in central and eastern Nepal. To expand accessibility, CSISA identified five hybrid varieties that perform well in the mid and far western parts of the country.
Wheat	An ex ante research study identified between "20,800 and 103,000 ha of currently fallow and rainfed cropland" in Bangladesh that "could be intensified during the dry season by shifting to wheat cultivation." To support intensification efforts, Bangladesh Agricultural Research Institute (BARI) developed and released four heat- and salinity-tolerant wheat varieties. In regards to fertilizer management, CSISA suggests that Bangladesh should reduce its official nitrogen fertilization recommendations by 33%.	Wheat research in India focused on the use of **ZT** and **early sowing**. A survey of farmers in Bihar found those practicing ZT had a yield increase of 19% compared to those not practicing ZT. On-farm research showed that when wheat planting was shifted from early December to early November, yields increased an average of 1mt per hectare. Moreover, research showed that three long-duration varieties averaged higher yields (4.58 t/ha) than three short-duration varieties (3.3 t/ha). CSISA researched the use of **Crop Manager**, an ICT-based decision framework, which allows farmers to determine best fertilizer combination for their fields. CSISA completed 129 on-farm trials in Bihar and Eastern UP using recommendations generated from Crop Manager. Finally, three herbicide/herbicide combinations were tested; results were provided to extension agents and the private sector to promote availability of certain herbicides.	As in India, ZT wheat was reported to outperform conventionally tilled wheat. However, improved varieties show yields 40-60% higher than local varieties, and research into fertilizer management suggests an additional $60 in fertilizer per hectare could result in an increase in profitability of $160 per hectare.

	Bangladesh	India	Nepal
Rice	CSISA staff trained farmers in the use of Good Agricultural Practices – high yielding varieties, on-time planting, spacing, and fertilizer application – and reported yield increases of nearly 10% in both seasons. Researchers also considered the efficacy of ZT (resulted in lower yields and profits; was not shown to be an effective practice) and direct seeded rice, which proved to be the most effective planting method. Finally, CSISA also conducted research on medium and long season varieties of rice.	Research comparing puddled transplanted rice (PTR) and DSR showed no yield difference in Bihar or Eastern Uttar Pradesh (EUP). Researchers in India focused on mechanizing planting. In Odisha, the use of drill seeding machines increased yields by .2 t/ha and decreased labor requirements. CSISA researched and developed new rice varieties, and enhanced existing varieties using marker-assisted breeding. As with their efforts on maize, the team relied on ICT solutions to provide specific fertilizer recommendations. Research comparing the use of herbicides compared to hand weeding (for weed management) showed yields doubled with the use of herbicides.	Research efforts focused on planting methods and improved varieties. Evaluations of DSR versus rice transplanted from nurseries showed no yield differential; however, DSR outperformed transplanted rice in cost savings (an estimated of $200USD per ha). In CSISA evaluations, hybrid rice outperformed improved varieties under high and low fertility levels. However, new varietal adoption rates in Nepal are low.

As noted in the introduction to this chapter and particularly in India, priority concerns included timely crop establishment (e.g., early sown wheat), and resource-conserving crop establishment and land preparation (ZT, DSR, and the app Crop Manager).

Phase II staff conducted 351 field trials for new strains; and published research findings (including 40 publications), short research notes, policy notes on the CSISA website, and brochures and technical manuals (https://csisa.org/technical-publications/).

CSISA Phase III: Research included:

LDS: By the end of Phase II, CSISA had secured an agreement with the Indian Council of Agricultural Research to train extension officers employed by the KVK to conduct field research for the LDS, which informs many partners about farmer practices in the field. In Phase III, CSISA published key findings from the LDS, and each KVK officer used data they collected to write a chapter in the publication on their region, both increasing KVK data collection skills and allowing KVK partners to have public recognition for their expertise and work. As of 2019, "data from 7,648 wheat fields and 10,069 rice fields [had] been uploaded" (CSISA III_Narrative-31Dec19, pg. 9).

In addition to continued work from Phase II on timely crop establishment (e.g., early sown wheat), and resource-conserving crop establishment and land preparation, in Phase III CSISA's research included:

Introduction of new climate-friendly varieties of seeds and diversification of crops: A majority of smallholder farmers in the areas under CSISA's purview rely on rain to irrigate their crops. Following years of heavy monsoon rains, CSISA researched a variety of flood-tolerant rice varieties.

Rice nurseries: to increase the availability of rice seedlings, CSISA encouraged the growth of rice nurseries to serve farmers at various times in the rice-growing season.

Promoted mechanical rice transplanting (MRT) in Odisha: Extending research conducted during Phase II, CSISA sought to increase the number of service providers offering mechanical rice transplanting operations and the number of farmers using them. CSISA developed and circulated a training module on MRT, worked with the Odisha government to shape MRT policy, conducted two trainings of trainers for extension officers, and researched where MRT might be most profitable.

Continued promotion of DSR: Research during Phase II and III demonstrated that DSR produced higher yields than broadcasted planting. CSISA also noted challenges with DSR. First, reporting from 2016 showed that the efficacy of DSR depends on ecological constraints (e.g., lowland versus highland ecology), and thus is not a one-size-fits-all intervention. CSISA also noted that "poor or uneven crop establishment and higher weed infestation are ... risks associated with DSR" (CSISA III_Narrative-31Dec19, pg. 3). In turn, weed control is more knowledge-intensive in DSR than in puddled transplanted rice because of the emergence of diverse weed flora, and CSISA has conducted research on adequate herbicides to use with DSR.

Integrated weed management (IWM): CSISA conducted research into weed prevalence, herbicide use, and herbicide efficiency in Odisha, EUP, and Bihar.

Promoted maize diversification in Odisha: Phase II identified crops for diversification in "Odisha's tribal-dominated plateau region, [which] is characterized by depleted soils along with low and variable rice yields associated with rain fed conditions" (CSISA III_Narrative-31Dec19, pg. 6). CSISA identified maize, in part because CSISA envisioned linking Odisha maize farmers with the poultry value chain for feed. CSISA also noted that maize could be "promoted as a women's crop as [it] does not displace other food security crops" (CSISA III_Narrative-31Dec19, pg. 6). CSISA conducted field trials of hybrid maize seeds with companies and the DOA to identify best varieties for local ecologies.

In Phase III, CSISA conducted 249 field trials (or broadly, research initiatives) and produced 11 publications.

Results Tracking Data

CSISA Phase II: CSISA used a participatory research approach to test and adapt new technologies for sustainable intensification **(CSISA II Results Tracker 1.2);** hub-level prioritization and transition strategies largely drove the research. The grantee reported that it met its output targets to conduct at least 75 technology verification trials to refine production and livestock feed technologies, and to study constraints to adoption of technologies such as DSR, mechanical transplanting, and ZT wheat. Although CSISA made progress towards its target to reduce postharvest losses by 10% benefiting over 100,000 farmers, especially women, it reports that scaling assumptions were "overly optimistic and targets not achieved" **(CSISA Results Framework Final, 2016).**

CSISA aimed to develop a new generation of rice varieties with enhanced genetic yield potential and traits for fodder quality, dry direct seeding, and heat tolerance improvements. It exceeded its targets to have at least 10 hybrid breeding lines for direct seeding and water-saving irrigation practices in national testing programs, and two elite advanced heat-tolerant lines nominated for varietal testing. It did not meet its target to have at least two hybrids released for cultivation, although it reported that 12 breeding lines were in advanced stages of testing in indicating that it was progressing towards this target.

The grantee released 17 new wheat varieties that have a higher yield potential and are better able to withstand the vagaries of climate change, exceeding its target (3-5 varieties). It also met its output targets to identify more than 100 new resistant lines, integrate these in the breeding program, and identify molecular markers for heat and drought tolerant varieties.

CSISA translated research into actionable products and insights **(CSISA II Results Tracker 1.3)**. Under this intermediate outcome target, CSISA reported on the development and dissemination of web and mobile-phone based applications, including site-specific nutrient management; dual-purpose rice, wheat, and maize varieties; and business models to support dissemination of technologies promoted by the grantee.

Most output targets were not specific enough for us to determine whether or not the targets were met, although there were enough details to show significant progress. For example, in collaboration with state universities and government partners, CSISA developed DSTs (e.g., Crop Manager) that provide location-specific fertilizer guidelines for farmers growing rice in Odisha and rice or wheat in Bihar and EUP, respectively reaching 2,000 and 20,000 farmer households. It also identified and facilitated the dissemination of a range of higher-yielding hybrid rice and wheat varieties, with some offered for license to the seed sector, and it developed business models for small machinery and other technologies.

CSISA Phase II established targets to improve policies and incentives that encouraged public-private partnerships in technology development and delivery. While the RT did not clearly show whether these targets were met, the RT does mention that several international and national private seed companies used CSISA's research to justify new or continued investments in product lines. CSISA also shared insights on gender dimensions of adoption of resource-conserving technologies with government and private sector partners, and organized learning events targeting policy reform.

CSISA Phase III: CSISA met or exceeded most of its milestones that aimed to raise the capacity of scientists and policymakers to improve their understanding of sustainable intensification technologies **(CSISA III Results Tracker 2.3)**. It worked specifically towards raising the capacity of the KVK system, providing trainings and workshops on participatory research methods, survey design, and digital data collection. It did not meet its milestone to converge State Department-led surveys and those implemented by the KVK, because of sampling differences and other technical challenges.

Part of CSISA III's R&D work focused on consolidating knowledge and developing strategies to build climate-resilient production practices in rice-wheat cropping systems **(CSISA III Results Tracker crosscutting 1.3/3.2/3.3)**. CSISA met most of its milestones. This crosscutting theme also addresses the needs of women **(CSISA III Results Tracker 1.3)**; as CSISA notes that its research on rice nurseries showed a high demand for quality seedlings. It therefore suggests rice nurseries create a significant scope of employment for women. Of the milestones not met, CSISA reported many were in progress. For example, CSISA is still working on using weather forecasts to inform the timing of establishment of rice nurseries, and reports planning to organize a monsoon forum to capitalize on research results to cope with climate extremes. Feedback mechanisms to formulate, strategize, and address the needs of farmers were used to promote diversification and rice-based agronomic management, and may have contributed to outcomes (CSISA III Progress Narrative Report, 2019).

Through its R&D work, CSISA III is also co-developing support programs for intensification of rice fallows in Odisha **(CSISA III Results Tracker 3.5)**. While the grantee met its milestone to conduct choice experiments to generate evidence on public investment options for rice fallow development, a publication of the results is still in progress.

As IWM strategies were considered essential for facilitating the adoption of sustainable intensification technologies **(CSISA III Results Tracker 3.6)**, the grantee conducted surveys to gather information on problematic weed species and practices, evaluated and validated IWM options, and conducted research with NARES partners to strengthen IWM strategies. CSISA largely met its milestones, building on private sector members of the DSR consortium to facilitate market development of new and safe products (CSISA Progress Narrative Report, 2019).

To support the development of precision agriculture, CSISA worked with the Soil Intelligence System initiative to deploy precision nutrient management recommendations **(CSISA III Results Tracker 3.7)**, and it worked on improving agro-advisory through knowledge and data integration **(CSISA III Results Tracker 3.8)**. While it is not clear from CSISA's monitoring data to what extent it met its targets for deploying precision nutrient management recommendations,[15] the SIS Progress Narrative shows progress towards the establishment and leveraging of a soil intelligence system. CSISA did not meet all its milestones for strengthening the foundations of agro-advisory services; it is working with partners on developing a platform that provides customized advisory messages to rice farmers.

CSISA's research also focused on agronomic practices that minimize the threats posed by wheat blasts **(CSISA III Results Tracker 3.9)**. CSISA reported that it met its milestones by conducting multi-locational field trials to test approaches that could reduce the risk of wheat blasts, and it supported marketing campaigns to bring knowledge of these risk reduction measures to farming communities.

In-Depth Interview Results

In-depth interviews reflected the research described in the program documents and results tracker.

While CSISA is not specifically about the development of capacity for R&D, some respondents to the in-depth interviews noted two areas where CSISA contributed to shifting the hegemonic paradigm of agronomy research in India. First, due to the success of the Green Revolution, agronomy in India had focused on single commodities (for example, a new variety of seed). CSISA emphasized "systems thinking," considering the entire calendar year and the multiple and interacting inputs needed to improve overall yield (while not discarding the introduction of new seed varieties). The respondents observed a change from assessing a "single component's" effect on a single crop to assessing the combination of inputs that can increase productivity in all crops throughout the year. Changes related to continually assessing bottlenecks and seeking solutions to those bottlenecks accompanied this "systems thinking," along with more openness to multi-

[15] The CSISA Phase III Results Tracker refers to the SIS report. However, the SIS report does not refer to the specific target outcome nor does the SIS monitoring data clearly report on the extent to which targets were achieved.

disciplinary (e.g., anthropology, economics, political science) approaches to understanding and solving problems.

> *This is how like, we can say, that CSISA has some sort of impact on agronomy. And the more about, I think, […] the system thinking, but before we have seen that most of the scientists even in the state department they were thinking in the […] components like rice crop and wheat crop. Because […], for example, if you want to do something with wheat you have to fix something in the rice also. Because if you want to bring your wheat sowing early, then you have to sow your rice crop early also. Because if you sow your rice crop late then you will harvest late, and your wheat will automatically be delayed.*
>
> –CSISA Stakeholder

Second, agronomy shifted to an increased emphasis on dissemination, within CSISA and to some extent through the KVK system. The LDS highlighted that farmers were not implementing many of the government-recommended practices (e.g., seed varieties, fertilizers), and helped the agronomy sector realize that it needed to pay more attention to the dissemination of research results and recommendations. One respondent noted:

> *[P]reviously, it was research first and extension follows, but now through the CSISA project it is that extension and research are happening at the same time.*
>
> - CSISA Stakeholder

Respondents to the key informant interviews did not tend to talk about or emphasize the research capacity-building aspects of the grantee outside of the LDS. Instead, they discussed their efforts to increase the uptake of research findings.

CSISA emphasized ZT early in Phase II implementation, but respondents reported that farmers did not immediately take up the technology. There were some problems with ZT, including issues with perennial weeds, the machines being unaffordable to smallholder farmers, low understanding of how to calibrate or maintain the machines, and imported machines not being suitable for conditions in India. CSISA had to develop a multi-pronged strategy to deal with these bottlenecks. First, the introduction of early sown wheat helped generate demand for ZT, because ZT shortened the period of time between rice harvest and wheat sowing. Second, CSISA helped to adapt the machines, and local manufacture started. Third, CSISA developed an entrepreneurial model where farmers with larger landholdings that could afford a ZT machine bought the machine and then rented the machine to smaller farmers. These "service providers" were motivated to understand how to maintain and calibrate the machines because the machines generated direct revenue for them.

> *So, what we said, that instead of laying out demonstrations [to farmers], you create service providers, our field technician; we convince them that you create service providers who will automatically promote zero tillage […]. So, instead of conducting so many demonstrations, we in fact created service providers and they did zero tillage.*
>
> - CSISA Staff

Online Survey Results

The majority of online respondents (16 of 19, or 84%) strongly agreed with the statement that CSISA strengthened research systems capacity. Thus, CSISA staff may simply not have

emphasized their activities focused on strengthening the capacity of the research system, or online respondents may have been reflecting the impact of the LDS trainings and activities.

Summary and Main Lessons Learned on Development

The respondents to the in-depth interviews emphasized two main points related to agronomy development:

1. Research and solutions are interdependent across the entire system and calendar year. Changes in one crop often require changes in other crops and/or changes in other aspects of agronomy such as planting techniques, weed management, and fertilization. Often (and this is related to the next point), these interactions take time to identify as problems and then develop comprehensive solutions.
2. Development of solutions should feed back into the needs assessments and agronomy research agenda. As solutions are developed, they often identify further issues that need resolution.

Many respondents reported that the underlying challenge for agronomy in India is climate change (and addressing climate change was an underlying rationale for the CSISA projects). However, climate change means that agronomy needs to adapt not only to counter the effects of input price inflation but to rapidly changing temperature and rainfall conditions, which require nimble and rapid innovation that is anticipatory and adapted to local conditions. These types of concerns led to the development of the KVK/LDS research activities to enable local institutions to have the capacity to engage in continuous research based on farmers' activities.

When asked what CSISA could do to strengthen the capacity of agricultural researchers, respondents to the online survey universally (19 out of 19) pointed to increasing the opportunities for learning exchanges. Two of the five top answers to this question related to increasing collaboration or learning exchanges from existing research institutes, two of the five top answers related to increasing resources available, and one answer related to increasing the capacity of researchers.

Scaling

CSISA's approach to scaling agronomy solutions, including dissemination of ideas and building the capacity of local stakeholders and institutions to scale or disseminate agronomy solutions.

Document Review

CSISA Phase II: Dissemination partners for Phase II focused on extension agents, and extension trainings and capacity building varied by crop and country. Project directors did engage in more high-level extension interventions, including a workshop led by CIMMYT and International Food Policy Research Institute (IFPRI) in Washington, DC in 2015, on strengthening research, extension services, and input markets in South Asia.

In Bangladesh, CSISA provided extension support to train farmers in best management practices. In India, extension support focused on wheat: CSISA officials shared quantitative results from early sown trials with extension agencies, and attended state departments of agriculture's annual pre-season workshops to share findings/benefits of early planting and ZT. There were no reported extension activities in Nepal.

At the end of Phase II, CSISA engaged KVKs to help disseminate technologies such as ZT, early sowing of wheat, DSR, and climate-resilient varieties of rice. Project coordinators in Phase II

noted that the number of project partners made the coordination of CSISA complex and at times "difficult to manage" (Final Narrative, pg. 25). CSISA also worked with the private sector to increase the availability of hybrid maize seeds (India, Bangladesh and Nepal) and with farmers-turned-service-providers to increase availability of ZT and DSR seed drills (especially in India).

Phase II trained 213 researchers and 4,250 intermediaries; collaborated with 185,000 farmers through trainings, demonstrations, and video screenings; and led at least 5,103 farmers to change their habits and behaviors.

CSISA Phase III: To scale knowledge and increase use of ZT, CSISA partnered with agricultural research universities in Bihar and EUP and with the Agricultural Technology Application and Research Institutes (ATARI in India), an extension training institute in Bihar; and conducted statewide trainings in Bihar.

CSISA continued to work closely with KVKs to disseminate information on early sown wheat and ZT practices. CSISA also developed and circulated Better Bet Guides on best practices in DSR, IWM, maize in Odisha, ZT, and early sown wheat, in multiple languages. Additionally, CSISA produced videos on ZT and early sown wheat, aired "radio jingles" on DSR on radio stations in Eastern UP, and published tips in Odisha newspapers.

CSISA also disseminated information about "timely plant operations" through "billboards, newspaper announcements, short message service messages through [Indian Farmers Fertiliser Cooperative's] advisory service, state extension, and JEEViKA (the largest livelihoods program in Bihar) and Precision Agriculture for Development (PAD) on maize production in Odisha" (CSISA III_Narrative-31Dec19, pg. 16). Phase III scaling partners include:

- **Private sector/value chain:** CSISA envisioned partnering with multinational companies such as Kellogg's and Bayer for "input and output markets"; it is unclear from project documents how well these partnerships were forged.
- **India state partners:** state DOAs, ICAR, and KVKs are biggest partners for scale.
- **International research institutes:** CSISA collaborates with the IRRI-run, multi-country Direct-Seeded Rice Consortium. Through consortium work, CSISA partnered with Corteva (a US agribusiness company), who will focus on "scaling DSR in Bihar" starting in 2020 through a project called "Rice Next" (CSISA III_Narrative-31Dec19, pg. 5).

In Phase III, CSISA trained 13,663 intermediaries (i.e., extension agents and farm service providers) and 4,091 farm-level beneficiaries; created 18 tools such as training modules, vulnerability maps, and printed guides; and reached over 2 million through CSISA publicity materials.

Results Tracking Data

CSISA Phase II: Catalyzing impact at scale required the mobilization of partnerships **(CSISA II Results Tracker 1.4)**. CSISA aimed to establish advisory committees and partnerships to create local ownership and align activities with government investment strategies. There is no mention of the establishment of advisory committees in the monitoring data or the Final Narrative (2016), but CSISA stated that regular interactions with ICAR and state- and district-level institutions resulted in deepened collaborative programming, adoption of improved recommendations (e.g., wheat planting dates), and new investment priorities (e.g., DSR). It also set the target to have at least 15 major partnerships that each will reach 10,000 farmers promoting CSISA's technologies.

During Phase II, CSISA worked on strategies to consolidate progress and sustain momentum for existing hubs, and the grantee designed modalities for operationalizing new hubs in EUP, Bihar and Odisha **(CSISA II Results Tracker 1.1)**. Several hubs (Haryana, Punjab, Tamil Nadu, and Pakistan) were transitioned to research institutes with the capacity to continue the activities without funding from CSISA. Using hubs to catalyze the adoption of new technologies, CSISA set a target to provide impact pathways, CSISA developed the capacity of its staff and public and private sector actors ("key agents of change") to play leading roles in accelerating impacts at scale **(CSISA II Results Tracker 1.5)**. CSISA trained hub staff and partners on participatory research methods, target user-driven communication strategies, and gender mainstreaming, and provided direct mentorship to self-help group leaders to develop women's leadership skills, meeting most of the related output targets. CSISA also exceeded its targets by developing the capacity of 2,500 service providers and 750 agro-dealers to develop their knowledge of agricultural technologies, inputs, and business development.

CSISA Phase III: Promoting the adoption of sustainable intensification technologies focused on mechanized solutions, and in particular on scaling ZT **(CSISA III Results Tracker 1.1/2.2)**. Most of the associated milestones were met, as the grantee raised awareness and shared evidence about the potentially higher yields with ZT.

To improve income-generating maize production in hill and plateau ecologies **(CSISA III Results Tracker cross-cutting 1.2/1.3)**, CSISA worked to facilitate maize supply chains, screening maize hybrids and disseminating best-bet maize agronomy technologies in Odisha. It facilitated the ability of mills to procure maize from the grantee's target geographies. It also reported that its collaboration with the State DOA and a network of partnerships helped to expand the area of market-oriented maize planted in plateaus; this collaboration could explain the grantee meeting most of its milestones related to this outcome target.

To support the development of women-inclusive livelihoods, CSISA aimed to provide high-quality agriculture information to more than 1 million women and disadvantaged groups. Milestones related to this outcome target, however, did not focus specifically on women but rather on farmers more generally. For example, CSISA aimed to distribute best-bet agronomy information through input dealers, or share videos and leaflets with information on raising rice-seedlings. CSISA reports on the partners involved and the number of farmers reached, but did not provide detail on their progress **(CSISA III Results Tracker 1.3)**. For example, the grantee distributed over 86,000 leaflets and fact sheets on rice seedling planting, early wheat sowing, and wheat blast mitigation to more than 64,000 farmers across project hubs, of which nearly a quarter were women.

Milestones for adoption of climate-resilient production practices were also met (**CSISA III Results Tracker 3.4),** as KVKs, the State Agriculture Universities, and the Department of Agriculture in Bihar and EUP adopted early wheat sowing as an innovation for wheat intensification. CSISA revealed that about 275,000 ha were planted for wheat at least five days earlier, exceeding its target (200,000 ha).

In-Depth Interview Results

Respondents to the in-depth interviews did not widely discuss capacity building for dissemination; rather, they focused on dissemination itself. One exception related to the LDS. As noted in the previous section, the LDS highlighted that farmers were not implementing many of the government-recommended practices (seed varieties, fertilizers, etc.), and helped the

agronomy sector realize that it needed to pay more attention to the dissemination of research results and recommendations. CSISA's practice of developing a cooperative "ecosystem for the adoptability of the technology" [CSISA Stakeholder] provides a model for this new way of thinking about dissemination.

The reported extent of farmer uptake of new technologies varied among respondents to the in-depth interviews, and farmer uptake of new technologies likely varies in different locations. Other respondents mentioned the success of the LDS. The LDS's impact on farmers is not yet clear, but respondents found it useful for understanding farmers' behaviors and thus shaping policies.

Several respondents cited CSISA's "bottom-up" approach – direct interaction with farmers and, especially, inviting farmers to field demonstrations – as a direct contributor to uptake and the success of CSISA. Further, CSISA acknowledged the heterogeneity of farmers' conditions. For example, while the ideal for early sown wheat is planting before November 15, CSISA also encouraged farmers to engage in "earlier" sown wheat. Thus, a farmer that used to plant wheat in mid-December could move to planting wheat in early December and still realize yield gains.

> *There are two [most effective ways of communicating research]. When we demonstrate at farmer's field. So, we bring farmers as well as actors and agencies on those sites. And once they see it, then that becomes the way we communicate with the new influencers. And at that matter, do you know which was not related to demonstrations was the dealers. So if there is anything which is aggregated with the production – for example, a variety, […] a hybrid or some improved […] hybrid science– so there we have to interact with the dealers. […] So [information] is mostly [passed]] farmer to farmer and from to dealers to farmers.*
>
> - CSISA Staff

Respondents also pointed out that CSISA was not just "bottom-up" but also made concerted efforts to build partnerships, shared communications, and established common understanding across partners in different sectors and levels – including local, state, and national government, universities, KVKs, NGOs, the private sector, media, and farmers. This reflected a limit on what CSISA could do by itself, and CSISA's recognition of need for existing institutions to buy into developed solutions for mainstreaming and scale-up. For all partners, CSISA needed to provide demonstrations of success; CSISA could build partnerships around successful ideas and technologies only. CSISA also allowed partners to "own" a new idea. Evidence alone, however, was not sufficient in all cases to convince partners, and building CSISA "as a brand" and trusted partner took time and was a continual process. Further, different partners wanted to see measures of success in different ways, and CSISA tailored both the message and the contents of the message for different stakeholders.

> *The research findings for any – if there is any new knowledge or new message it is required to send. [CSISA …] post to us at the state level. We sit and analyze what are the messages which is very beneficial for us or we jointly analyze those things. And then through our office and through our reports it is sent to the field to the districts to abide by those orders and propose to support the farmers.*
>
> - CSISA Stakeholder

One respondent noted that these partnerships, while intermediary to the overall achievements of the grant project, had other benefits that were less visible – for example, they could show that a program had only limited success, and this evidence motivated the government to limit its spending on that program.

Online Survey Results

All respondents to the online survey agreed or strongly agreed that CSISA strengthened the capacity of extension agents to disseminate and promote new farmer technologies and tools. However, online respondents also indicated that extension agents still had room to increase their capacity to disseminate and promote new tools to farmers, including increasing training on the tools to be disseminated (79%), and increasing linkages to better engage private sector partners (74%).

Summary and Main Lessons Learned for Scaling

CSISA successfully integrated public sector organizations throughout Phases II and III in India, and also focused on including private sector organizations in their work. (The scope of engagement with the private sector is unclear from documents and interviews, although they certainly engaged with NGOs such as JEEViKA, and worked with service providers, among others). At the same time, most respondents emphasized field demonstrations directly involving farmers as a critical component for uptake and scaling.

One challenge to scaling that respondents to the in-depth interviews noted related to the systemic interventions, which require the alignment of several factors (for example, seeds and other inputs being available on time for earlier sowing, and machines being available and operational). If one aspect fails or if an exogenous factor such as poor rainfall results in a poor harvest, farmers may become suspicious of the innovation effort. Thus, systemic interventions may need a longer timeline for mainstreaming and showing impact than simpler interventions. A few respondents mentioned the need for careful planning to counter these factors.

Dissemination on the scale of agriculture in India is a very large task, and partnerships and time are necessary for dissemination and awareness raising. Lessons learned include thinking about dissemination from the start of the project, planning for it, and building strategic partnerships also from the beginning of a project. Other lessons include being flexible in the dissemination messaging and being responsive to partners' needs when developing dissemination and awareness raising plans.

Policy Development, Institutionalization, and Sustainability

CSISA's approach to ensuring longer-term adoption of their research, agronomy solutions, and tools, including plans to institutionalize their work through local stakeholders and institutions.

Document Review

CSISA Phase II worked closely with the regional government in Bihar, which incorporated early sown wheat into its annual recommendations. CSISA leaders had established national and international recognition within the agriculture community, which helped them to develop partnerships. CSISA worked to collaborate with the state governments of Odisha and Bihar to streamline policies on mechanization.

CSISA Phase III proposed to work in four core policy areas: seed systems, agricultural mechanization, risk management, and input markets. CSISA revised the latter category to soil fertility and fertilizer markets. CSISA reduced policy work in the seed sector due to staff

turnover. In 2018-2019, mechanization policies in Odisha were slowed: "[d]ue to non-approval of project proposal from the state department of Odisha, field activities on the assessment of proposed mechanization policy reforms could not be undertaken. A change in work plan was initiated to generate valuable insights on the implementation of machinery subsidy schemes to better target the beneficiaries" (Results Tracker-31Dec19, AS/41). In 2016, Bihar adopted CSISA's recommendation of "expanding area under DSR as a state priority... [and] tips on DSR ... [were] endorsed by the Odisha State Department of Agriculture" (2016 Progress Narrative, pg. 3). CSISA engaged in high-level meetings on fertilizer subsidies (CSISA-SIS also did more work in this area).

Results Tracking Data

CSISA Phase III: CSISA worked on policy reform to support the spread of sustainable intensification technologies. Some of the activities CSISA scheduled in support of policy reform could not be implemented as planned. This included its work on policy and regulatory reform for seed systems and markets **(CSISA III Results Tracker 4.1)**, improving incentives of scale-appropriate mechanization **(CSISA III Results Tracker 4.2)**, and policy reform for balanced fertilizer use **(CSISA III Results Tracker 4.3)**. Reasons reported by CSISA are respectively staff phase-out, non-approval of a project proposal, and local elections that caused a delay in field implementation. It met its milestone, however, to disseminate findings from an assessment of farmers' willingness-to-pay for risk management products **(CSISA III Results Tracker 4.4)**, in particular agricultural insurance under the government sponsored crop insurance scheme.

In-Depth Interview Results

CSISA in-depth interview respondents emphasized two main approaches the grantee used to work towards mainstreaming and sustainability. First, they reported that farmers want to adopt and sustain interventions when agronomic practices introduced by CSISA provide farmers with net benefits. Second, to enhance mainstreaming, CSISA builds linkages between farmers, service providers, research institutes, and local governments, and seeks to extend the most successful elements of the CSISA model into the programming of government institutions at all levels.

While CSISA's agronomy research demonstrated substantial improvements in yields and potential farm efficiency, low demand and limited access to inputs and credit in some cases challenged sustainability, particularly for the required combined system changes (e.g., early sown wheat) and farmer investments required by mechanization (e.g., ZT).

While CSISA had been building evidence and relationships for institutionalization throughout Phase II, at the end of Phase II CSISA staff reported a shift to even greater and more formal institutionalizing of findings. As such, CSISA initiated the partnership with the KVK that became a major objective of Phase III. CSISA envisions KVK to not only help with the promotion of technologies but also take the reins of future research through the LDS.

Many stakeholders worried that the system of collaboration and communication that CSISA fostered might disappear when CSISA ends. CSISA developed the LDS in part to develop institutional responsibility and capacity within the Indian system to undertake needs and adoption assessments—two critical components of the larger agronomy research system. To institutionalize the LDS, CSISA is developing a roadmap and implementation plan for ICARs who expressed the commitment to implement the LDS. However, some interview respondents reported being concerned about sustaining the LDS beyond the life of the project. Respondents still considered limited capacity to implement and analyze the surveys a challenge, and perceived

the LDS to be a significant departure from existing ICAR practices. Overcoming those who want to maintain the status quo will require consensus building, and further developing capacity still requires organizing more trainings and workshops.

Respondents also reported that external factors also influence the sustainability of outcomes. For example, respondents reported that subsidies on ZT were relatively low compared to for rotavators, in spite of the yield and labor-savings advantages of ZT over rotavators. CSISA's policy reform objectives included addressing barriers to farmers' receiving agricultural machinery subsidies.

Summary and Main Lessons Learned for Policy Development, Institutionalization, and Sustainability

Researchers present evidence to farmers, stakeholders, and government officials, but policy development relies on more than just evidence. Respondents reported that CSISA's successes in policy development hinged on both being a trusted source of information and working with multiple partners to develop and communicate policy ideas to policymakers.

CSISA's approaches to scaling and implementing early sown wheat, ZT, and the LDS suggest that different technologies may need different approaches. Institutionalization of early sown wheat relied on demonstration to farmers (at least initially) and then collection of systematic data to convince universities and KVK about the efficacy of the innovation; in Bihar, official policy soon followed.

For ZT, after initial setbacks, CSISA worked to identify a market solution that exploited existing institutional arrangements (such as the government subsidy for ZT machinery). The market solution is inherently intended to sustain the solution – in this case, service providers make money renting the ZT machine, farmers with small land holdings benefit from lower production costs in net and higher yields, and so on. "Policy development" in this case may not require "an official government policy."

The LDS work also focused on sustaining *research* rather than on sustained uptake of an agronomic solution. For the LDS, CSISA stressed involving KVK staff from the beginning in all aspects of the survey, from data collection to write-up and analysis, and helped KVK staff publish results. CSISA respondents to the in-depth interviews believed that having KVK staff understand, own, and use the data and results of the survey would create demand for more data and help institutionalize the LDS processes.

Impacts

CSISA-developed agronomy solutions uptake by farmers, increased productivity by farmers, and strengthening of supply chains.

Document Review

CSISA Phase II: Two of CSISA's objectives were to deliver improved varieties of wheat and rice to partner countries. CSISA-developed wheat varietals "account for 18% of sales in India, 24% in Nepal, and 34% in Bangladesh" (Final narrative, pg. 4). However, reports contained conflicting numbers: one document details delivering "17 new wheat varieties that have superior yield potential and are well-buffered against the vagaries of climate change, have greater resistance to biotic stresses, are fully adaptable to the CA practices and have consumer preferred end-use qualities," but also reports that "partners in national programs released 49 new [wheat] varieties in India, Nepal, and Bangladesh" (Final narrative, pg. 4).

CSISA organized its interventions in broad categories, reported the uptake of each category based on the number of adopting households, and by the end of Phase II reported that over 2 million households had adopted at least one of CSISA's technologies (Table B4).

Table B4. CSISA intervention categories

Intervention	Adopting households
Timely crop establishment	702,227
Stress-tolerant and high-yield cultivars	1,166,845
Resource-conserving crop establishment and land preparation	197,353
Safe and effective weed control	175,912
TOTAL	2,242,338

CSISA generally does not differentiate adopting households by country.

Bangladesh: Bangladesh Agricultural Research Institute (BARI) released four heat- and salinity-tolerant wheat varieties. To support wheat adoption, CSISA held trainings and demonstrations that resulted in an estimated 80,000 new farmers adopting wheat.

India

Rice: CSISA released improved rice varieties. In both Bihar and EUP, CSISA reported the increased use of hybrids and improved yields.

Wheat: Between CSISA Phases I and II, wheat yields increased two-fold in Bihar and nearly two-fold in EUP, and 340,000 farmers in Bihar and 280,000 farmers in EUP adopted early sowing recommendations. After the Bihar officially adopted CSISA's findings on early sown wheat in 2013, the next year, "the area under early sowing of wheat in [Bihar in] 2014–15 increased by an estimated 37% to exceed 62,000 hectares."

The number of ZT service providers (SPs) in Bihar increased from 17 in 2010 to 1,624 in 2015. During the 2014-15 season, 40,000 hectares of ZT wheat was sown.

Nepal: CSISA reported working with private and public actors to make improved wheat varieties, hybrid rice, and hybrid maize more available, and to "increase the market availability of seed drills ... to aid the expansion of DSR rice and ZT wheat," though it is hard to determine the success of these efforts from project documents (Final Narrative, pg. 11).

CSISA Phase III

Early Sown Wheat: Despite positive reporting, routinely collected data do not specify or estimate how many farmers sow wheat early (or "earlier") in CSISA Phase III documents.

Zero Tillage: For the first two reporting periods of Phase III, CSISA exceeded its targets for new and continuing land cultivated using ZT.

Maize: Encouraged by results on maize production, Odisha's state "Maize Working Committee ... requested CSISA to expand its intervention to other agriculturally distressed districts ... In Mayurbhanj district, CSISA has already achieved considerable scale (5000+ ha) by [2018]. Sustainable intensification practices of maize were selectively spread in three more districts; in "total, 1,982 households, 26% of them women farmers practiced improved methods of maize cultivation on 2,403 ha" (CSISA III_Narrative-31Dec19, pg. 7).

Results Tracker

CSISA Phase II: The RT of Phase II of CSISA showed achievements on most output targets (in rows with boldface in Table B5). Overall, we found that CSISA achieved a third (10 of 30) of the output targets and did not meet 10% (3 of 30). We could not determine results for about 50% of the output targets due to a lack of clarity, and 7% (2 output targets) of the output targets were missing (see the introduction to the appendices for definitions of lack of clarity and missing).

Table B5. Results framework for CSISA Phase II

	Target exceeded	Target met	Target not met	Target/actual lacks clarity	Target/actual missing	Total targets
1. Dissemination of production and postharvest technologies		**5**	**2**	**6**	**2**	**15**
1.1. Road map for transitioning existing hubs		2			1	
1.2. Participatory technology testing and adaptation		2	1	1	1	
1.3. Translating research into actionable products and insights			1	3		
1.4. Mobilizing partnerships for catalyzing impact at scale				1		
1.5. Strategic capacity development		1		1		
2. Crop and resource management practices for cereal-based systems				**3**		**3**
3. High-yielding, heat- and water-stress-tolerant rice varieties	**2**		**1**			**3**
4. High-yielding, heat- and water-stress tolerant wheat varieties	**2**	**1**				**3**
5. Improved policies and institutions for inclusive agricultural growth				**2**		**2**
6. Project and data management, communication, and evaluation				**5**		**5**
6.1. Project management				1		
6.2. Data management and communication				3		
6.3. Project evaluation				1		
Total	**4** (13%)	**6** (20%)	**3** (10%)	**16** (52%)	**2** (7%)	**30**

CSISA Phase III: The most recent monitoring data of CSISA Phase III is from November 2019 (Table B6). The RT of Phase III of CSISA showed they had met sub-targets under each of the primary/intermediate outcome targets,[16] but does not report on progress against output targets (the rows in boldface).

We found that had CSISA met or exceeded over 60% (35 of 58) of the sub-targets to date, and that 28% of the sub-targets were not met. Some of the sub-targets lacked clarity (5%), and several descriptions of sub-targets were missing (3%).

[16] The RT of CSISA Phase III has grouped some intermediate outcomes that covered a theme (e.g., managing climate risk) together but it does not report on every intermediate target outcomes as defined in the RF, which is the reason the table does not include some intermediate target outcomes.

Table B6. Results framework for CSISA Phase III

	Target exceeded	Target met	Target not met	Target/actual lacks clarity	Target/actual missing	Total targets
1. Widespread adoption of sustainable intensification technologies		**2**		**1**		**3**
1.3 Delivery of high-quality agriculture information to >1M women and disadvantaged groups		2		1		
2. Mainstreamed innovation processes	**1**	**3**	**1**		**1**	**6**
2.3 Improved understanding of potential of sustainable intensification technologies	1	3	1		1	
3. R&D to support scaling of sustainable intensification	**1**	**16**	**6**	**1**	**1**	**25**
3.3 Adoption of water and labor-saving practices in rice production		5	1		1	
3.4 Building resilience to temperature extremes	1	1				
3.5 Foregoing fallows		2	1			
3.6 Sustainable weed management practices		5	1			
3.7 Precision nutrient management recommendations				1		
3.8 Precision irrigation scheduling recommendations		1	3			
3.9 Risk-reducing agronomic practices to minimize wheat blast		2				
4. Policy solutions to scale sustainable intensification technologies		**1**	**2**	**1**		**4**
4.1 Policy and regulatory reforms for seed systems				1		
4.2 Investment incentives for scale-appropriate mechanization			1			
4.3 Policies reforms for balanced fertilizer use			1			
4.4 Investment incentives for risk management products		1				
Cross-cutting target outcomes		**11**	**7**	**1**	**1**	**20**
Cross-cutting (1.1/2.2) - Accelerating the emergence of mechanized solutions		2	4			
Cross-cutting (1.2/1.3) - Maize production in hill and plateau ecologies		4		1	1	
Cross-cutting (1.3/3.2/3.3) - Coping with climate extremes in rice-wheat cropping systems		5	3			
Total	**2** (3%)	**33** (57%)	**16** (28%)	**4** (7%)	**3** (5%)	**58**

In-Depth Interview Results

In-depth interviews, in general, reflect the achievements reported in grantee documents and results tracking. Most respondents pointed to CSISA's role in increasing the uptake of mechanization (such as ZT) and the shifting of the timing of crop plantings (such as early sown wheat) and associated techniques.

> *Main achievement is the introduction of new technologies with the help of CSISA; this is the main achievement. Now more than 30-40% of famers are using zero tillage just because of CSISA. This is just my area, I don't have knowledge of other areas. DSR methodology still 5% of farmers are using DSR. [… W]e have introduced zero tillage for green gram and we have used this technology in black gram and lentil cultivation. This is the main achievement of CSISA – they have given the opportunity for farmers to learn new technologies.*
>
> - CSISA Stakeholder

> *If I list the main achievements 1, 2, 3, the main achievements [of CSISA are:] First, the farmers are machine friendly. Number two, the farmers are now molecules friendly, different chemicals friendly, particularly weed control. Micronutrient also, farmers are now using, they have learned that balanced use of fertilizer is a better result, it works. Third, the sowing time. Previously farmers were doing the rice starting at the end of June, now farmers are starting in June, even some farmers are starting in May also. This has given more time for the winter crops and simultaneously with the introduction*

of machines and tools, total productivity of the rice-wheat cropping system, which is the most dominant in our area, has boosted.

- CSISA Stakeholder

Other respondents mentioned the success of the LDS which CSISA and local partners (KVKs and ATARIs) have implemented in many areas of India, as discussed in Section 5 on scaling.

CSISA staff reported a flexible approach to overcoming barriers to achieving results. As mentioned in Section 3, CSISA's engagement with ZT provides an example of this adaptability. CSISA had to develop a multi-pronged strategy to deal with the bottlenecks to adoption of ZT, and use systems thinking about the solutions to low uptake.

So the early sowing that's starting the main thing, because this doesn't involve any monetary input or any machinery into this. So it's just about to break the mental blockage both of the farmers and the scientist also. So doing all these on farm trials, collecting the data, doing public harvest, doing the field days, I think that helped us break the mental blocks. Still, like I remember that in some of the meetings, like people I heard even the scientist say in their whole life they never have seen this around like 7 tons of wheat harvesting in Bihar. It's the first time they are seeing on the farmer's yield in those trials. So that's how it helps to break the mental blockage.

But in terms of zero-till, because you need some sort of a whole value chain of the machinery. So you need the machines, you need all these repairs, all the spare parts. […] So we, then we developed a lot of technical trainings also – how to maintain all these machines.

- CSISA Staff

Respondents listed other challenges, many of which are likely common to any agronomic research activity. These included battling conventional wisdom, especially in shifting from a "one commodity" paradigm to a systems or management paradigm, the limits of CSISA's resources in comparison to the scale of India, farmers' lack of capital and risk aversion, and being truly multi-disciplinary while at the same time keeping a diverse and geographically separated staff on the same page.

Summary and Main Lessons Learned for Impact

The main lesson learned from CSISA with respect to impact is that doing the needs assessment, research, scaling, and dissemination correctly does lead to impact. Starting with an area where there is a clear yield gap (such as there was for wheat in Bihar and EUP), it is necessary to do the following:

- Develop agronomy solutions that address that yield gap, and that cost farmers no more and preferably less than current practice.
- Work across stakeholders to demonstrate and establish credibility of solutions.

Partnering with existing networks for dissemination allowed CSISA to obtain noticeable impacts for early sown wheat. Even this process is complicated: adaptation, reworking communication, identifying bottlenecks, and solving problems were all necessary along the way.

B2: N2Africa Summary

This chapter summarizes the data collected for the N2Africa projects (Phase I and II), and, based on the data collected, provides lessons learned from the N2Africa projects' implementation. The chapter starts with a brief description of the project. Sections reflecting different parts of the Agronomy Grants Framework follow (the chapters of the main report body also follow this structure). For each of these sections, we present the data from up to four different sources (document review, review of the results trackers, in-depth interviews with grantees and stakeholders, and the online survey with grantee stakeholders; not all data sources are available for all parts of the framework). Each section concludes with a sub-section on lessons learned. The introduction to the appendices provides definitions and content for each of the sections of this chapter.

The N2Africa use cases focused on project work in Ethiopia addressing inoculants (i.e., to demonstrate how inoculants can improve yield and how to increase overall use of inoculants) and women's empowerment (i.e., integrating women in all aspects of the project). The use cases were referred to in the qualitative in-depth interviews to elicit responses. The use cases are not discussed in detail in this appendix but are discussed in the subsections based on in-depth interviews. The interviews for N2Africa focused primarily on the work of the grantee within Ethiopia, and almost all responses relate to the work in Ethiopia. This scope is narrower than among the other data sources presented for N2Africa; the other data sources include examples of findings from multiple countries.

List of Acronyms and Glossary of Terms

BNF	Biological nitrogen-fixation
CIAT	International Center for Tropical Agriculture
EIAR	Ethiopian Institute of Agricultural Research
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
PPP	public-private partnership
TOT	Training of trainers

Narrative Description of N2Africa's Activities

N2Africa was a decade-long project (September 2009–June 2019) based out of Wageningen University that sought to enhance legume production in Africa through improved legume varieties and biological nitrogen-fixation (BNF) technologies, including fertilizer and inoculants (nitrogen-fixing bacteria). The project spanned two phases and 11 countries.

The project used a development-to-research model, which entailed continuously testing and refining technologies through field trials, monitoring and evaluation, developed in Phase I and implemented in Phase II. Additionally, N2Africa partnered with scientists, agribusiness entities, and farmers to develop context-specific recommendations.

Phase I (September 2009–February 2014)

The first phase of the project ($21.8 million) partnered with the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA), and country-level partners to research and develop best-bet crop varieties, fertilizer and inoculants for four types of legumes (soybean, cowpea, groundnut and common bean) in DR Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda and Zimbabwe. All countries had equal focus in Phase I. This work included:

1. **Conducting variety trials to find "superior varieties" of legumes** on the basis of "agronomic traits and farmer and market acceptance," including resistance to certain pests or disease (2014 N2Africa Final Report, pg. 3). All in all, the team identified seven soybeans, six beans, six cowpea and seven groundnut varieties they deemed superior for particular regions.
2. **Conducting research into soil nutrient deficiencies**, which informed the development of fertilizer blends in collaboration with private sector partners and the development of inoculants with country-level partners.
3. **Supporting capacity building** in partner countries, including training scientists in rhizobiology, developing lab protocols, and sponsoring 17 MSc and six PhD students.
4. **Disseminating information** on legume varieties and BNF interventions through training of trainers and farmer groups, and disseminating sample seeds, fertilizers and inoculants through field demonstrations. In total, N2Africa reports reaching ~252,000 farmers during this phase.

Phase II (November 2013–June 2019)

The second phase of the project ($30.9 million) included additional countries at the request of the foundation (Ethiopia, Tanzania, and Uganda) and different partners: International Livestock Research Institute (ILRI) and the University of Zimbabwe. Phase II included a bridging phase to allow N2Africa to conduct a detailed stakeholder analysis of the three new 'core' countries.

Core countries and crops: Ethiopia (chickpea, common bean, faba bean, soybean), Ghana (groundnut, soybean, cowpea), Nigeria (groundnut, soybean, cowpea), Tanzania (common bean, groundnut, soybean) and Uganda (common bean, groundnut, soybean).

Tier 1 countries: DR Congo, Kenya, Malawi, Mozambique, Rwanda and Zimbabwe

Five objectives guided Phase II:

1. **Project strategy for delivery:** During this project phase, N2Africa established 257 total public-private partnerships (PPPs), supported 103 MSc and PhD students, and produced country-level policy recommendations for the legume sector in Ethiopia and Tanzania.
2. **Delivery and dissemination of legume technologies:** The project used a variety of strategies to disseminate technology and information, including:
   - Partnering with the private sector to produce and/or distribute inputs, including seeds, fertilizer and rhizobial inoculants (achieved inoculant marketing in every project country)
   - Working with farmers' groups and unions to collectively market legumes (e.g., in Ethiopia the project worked with cooperative unions)

- Through field demonstrations, radio and texting services to reach farmers directly.[17] In 2019 alone, N2Africa "reached" 677,495 farmers.[18]

3. **Empowering women to increase benefits from legume production:** The project envisioned serving female farmers through increasing access to labor-saving tools such as herbicides, and making sure women were present at training of trainers (the project reported that 30% of those trained were women).
4. **Tailoring and adapting legume technologies to close yield gaps and expand the area of legume production within the farm:** N2Africa developed and tested recommendations for best-fit technologies by country, region, and legume. For instance, in Ethiopia, the project developed 35 unique recommendations for fertilizer and inoculant use by grain legume crop and location.
5. **Enable learning and assess impacts at scale through strategic M&E:** N2Africa engaged in assessment activities throughout Phase II, including hiring external consultants to assess specific aspects of the project and the execution of an impact analysis study, which measured both knowledge about and use of project technologies (2018–2019).

Needs and Demand

This section describes how N2Africa identified agronomy research needs, and the target users of the research and how they prioritized the agronomy research needs.

Document Review

The three main needs identified for N2Africa Phase I included: nitrogen-depleted soils that required biological nitrogen-fixation technologies; value chains that required strengthening to respond to high demands for legumes, especially from "top-end buyers" who require reliable products; and increased capacity in rhizobiology research. N2Africa Phase I identified farmers, scientists, technicians, graduate students (MSc and PhD), agro-dealers and private sector actors as target users with these needs.

N2Africa Phase II's theory of change targeted farmers (emphasizing the very poor and women), agro-dealers, input suppliers, value chain actors, students, scientists, and national research institutions. While Phase II continued work in some Phase I countries (mainly Ghana and Nigeria), the project also worked in new countries: Ethiopia, Tanzania and Uganda. The four main needs identified for Phase II included: poor legume productivity, poor diets and weak support to women and very poor farmers, lack of effective legume input supply and output market chains, and limited national capacity in legume technology research and dissemination. N2Africa Phase II identified the following target users in this area: farmers, scientists, students, agro-dealers, input suppliers, legume buyers (value chain) and national research institutions.

In-Depth Interview Results

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[17] Many N2Africa dissemination tools can be found here: https://n2africa.org/agem

[18] The project defines *reach* as "awareness and knowledge gained through dissemination approaches such as demonstrations, adaptations, field days, radio, video shows, SMS, etc by group of farmers" (N2Africa Annual Report 2019, pg. 9)

Interview respondents described a participatory process in Phase II involving a combination of a background review of secondary literature, bringing together key partners in a workshop, and prioritizing locations, partners and targets for the project.

> "*We usually, you know, work with grassroot … project partners, that is smallholders, farmers. They always ask us for improving, you know, soil fertility quality. They ask us for improved seeds. … The demand always come from down from the grassroot.*"
>
> - *N2Africa grantee staff*

Online Survey Results

Eighty-four percent (16 of 19) of the online survey respondents reported that N2Africa prioritized their research based on the agronomic constraints limiting productivity, and 68% (13 of 19) reported that the needs assessment of beneficiaries was the most important factor. Interest from partners with existing dissemination networks was identified by 53% of respondents (10 of 19).

Slightly more than half (10 of 19) of online respondents thought N2Africa had a good understanding of how to assess demand for agronomic research conducted under the grant project, whereas 42% (8 of 19) felt the project had an average understanding.

All (19 of 19) respondents to the online survey identified smallholder farmers as the main target users of N2Africa's research, which is consistent with the project's overall goals. The majority (15 of 19) also identified agricultural extension agents and government sector agronomists/scientists as main target users. Slightly more than half (10 of 19) of online respondents thought N2Africa met some, but not all, of the target users' needs; the remainder reported that nearly all of the target users' needs were met. For more survey results, please see Appendix E.

Main Lessons Learned on Needs Assessments and Demand for Research

N2Africa Phase I research priorities appear to have resulted in significant strides in inoculant production, rhizobia selection, and rhizobiology research capacity. In Phase II, the needs assessment for research and the target users appear to have been aligned with the theory of change identified in this phase, even if the reach of these target users was uneven or difficult to ascertain. Some of the survey results also suggest that prioritizing research was based on agronomic issues that limit productivity and based on the needs assessment of the beneficiaries. The project's participatory approach and engagement of partners may be reflected in these consistent observations about N2Africa's needs and demands for research.

Development

This section describes N2Africa's efforts to improve the capacity of local stakeholders to undertake research and development; research undertaken; and tailored agronomy solutions developed.

Document Review

Phases I and II both achieved success in capacity building. In Phase I, the project sponsored 17 MSc and six PhD students, and involved "140 scientists, technicians, farm liaison specialists, and others in nine countries, 3% of whom are women" in rhizobiology activities and trainings (2014 N2Africa Final Report, pg. 5). Phase II supported 79 MSc/MPhil students (35% female) and 24 PhD students (42% female); in Ethiopia, it supported three PhD (all male) and nine MSc (eight male, one female) students. Of 103 supported students at MSc and PhD levels, 36% were

women, and 72 MSc/MPhil and 9 PhD students completed their studies (N2Africa Annual Report, 2019). In both phases, the grantee also developed extensive partnerships with state research institutions in the countries of focus.

In Phase I, the project also developed best practices adjusted to local conditions. N2Africa used a delivery and dissemination model to guide their work. A total of 266 variety trials of bean, cowpea, groundnut, and soybean were conducted in different field sites and settings during Phase I, with 28 "superior varieties" identified (nine soybean, six bean, six cowpea, and seven groundnut) (2014 N2Africa Final Report, pg. 3).

In Phase II, N2Africa conducted three types of trials (diagnostic, demonstration, and adaption) in Ethiopia in 2016, 2017, and 2018, to assess common bean, chickpea, fava bean, and soybean varieties at project sites (N2Africa Annual Report 2019, pg. 34). Demonstration and adaption trials were especially important for the research cycle, as they provided farmers the opportunity to evaluate and voice their favored technologies.

In addition to increasing legume production, N2Africa also researched whether improved nitrogen fixation increased the size and nutritional quality of legumes. In both Ethiopia and Ghana, the project found increases in seed weight and protein content, and increased digestibility, in the soybean and common bean. Additionally, a grantee-supported Ghanaian PhD student found "enhanced protein content in fresh cowpea pods" (N2Africa Annual Report 2019, pg. 38). Another PhD student from Ethiopia found "significant effects of inoculation and P fertilization on protein content of ... common bean, cowpea and soyabean" (N2Africa Annual Report 2019, pg. 38).

Results Tracking Data

N2Africa trained young African professionals enrolled in graduate degree programs in nitrogen fixation and legume intensification research **(Results Tracker 1.5)**. Apart from a target to formalize research and dissemination plans, which the project met, no targets were set for the number of African professionals trained. To ensure sufficient capacity to conduct high-quality inoculant research, N2Africa also contributed to the development of the national biofertilizer/inoculants standard operation procedures (SOP) **(Results Tracker 4.8.1),** for which it exceeded its targets.

A major focus of N2Africa was the evaluation and identification of new elite strains, especially in the area of rhizobiology, for inoculant production **(Results Tracker 4.6.2)**. Evaluation of inoculant strains occurred across agro-ecologies under greenhouse and field conditions, before the grantee began inoculant production. N2Africa aimed to have six rhizobia strains identified for inoculant production, but it reports that 920 candidate strains were initially evaluated.

N2Africa also included a target for the number of best-fit recommendations available for all targeted legumes and in each country **(Results Tracker 5.5.1)**. Development of these best-fit recommendations is the result of the grantee's agronomy research and extensive partnerships with multiple organizations. The grantee met its target to have 16 best-fit recommendations available in each country.

In-Depth Interview Results

Interviews identified some of N2Africa's research capacity strengths, such as the PPPs established in Ethiopia. Through involving the government through land used at its research stations and working with farmer groups to monitor seed quality and production, the legume crop

was expanded and farmer groups had seeds for future generations. Linkages were also developed between producers, research systems, policymakers, sellers and brokers/exporters. For example, the research system helped to establish the right technology; sellers and exporters sat together and planned what to do. Given that women's empowerment was one of the project's goals, interviewees commented that women were involved in research activities, among others.

Online Survey Results

Almost all online respondents strongly agreed (9 of 20, or 45%) or agreed (10 of 20, 50%) with the statement that N2Africa strengthened the capacity of the regional or national agricultural research system (NARS) to conduct agronomic research. Respondents also identified a number of changes N2Africa could make to strengthen the capacity of agricultural researchers. Eighty percent (16 of 20) recommended improved collaboration with key research institutes, 75% recommended additional lab resources/instruments and other technical resources, and 70% recommended additional training in research and analysis.

Summary and Main Lessons Learned on Development

N2Africa improved the capacity for research and development in important ways. In Phase I and II, the main paths for capacity development involved sponsorship of MSc, PhD and MSc/MPhil students, and rhizobiology activities and training for stakeholders such as scientists, technicians, and farm liaison specialists in nine countries, 30% of whom are women.

In Ethiopia, interviews identified N2Africa's research capacity strengths through PPP. For example, government partners who provided land used at its research stations worked with farmer groups to monitor legume crop seed quality and production; this was ultimately successful. Successes in research capacity were also validated by survey respondents, who agreed that N2Africa strengthened the capacity of regional or national agricultural research. Nevertheless, more can be done to improve the agricultural researchers' capacity. In both Phases I and II, the project engaged farmers in research, especially important voices to have present in those research activities. In Phase II, demonstration and adaption trials were especially important for the research cycle, as they gave farmers the opportunity to evaluate and voice their preferred technologies.

N2Africa also researched whether improved nitrogen fixation increased the size and nutritional quality of legumes, in addition to conducting increased legume production research. The project found increases in a number of favorable aspects such as protein content and seed weight in two types of beans in Ethiopia and Ghana. Further, N2Africa-sponsored students in these two countries conducted research with promising results regarding increased bean protein content and the effects of inoculation and P fertilization on protein content, an example of how the project's capacity-building and research activities built upon each other.

Scaling

This section describes N2Africa's approach to scaling agronomy solutions, including dissemination of ideas and building the capacity of local stakeholders and institutions to scale or disseminate agronomy solutions.

Document Review

N2Africa Phase I used ToTs (58% of farmers trained in training of trainers were women), field demonstrations, and collaborations with farmer groups, NGOs, and agro-dealers. N2Africa also disseminated sample seeds, fertilizers, inoculants, and crop management best practices. The

project held six trainings for 166 agro-dealers in total from all project countries on topics such as BNF technologies, legume marketing and pest management.

In reflecting on its work in Phase I, N2Africa realized that "limited access to input supply and output markets often constrained farmers to invest in legume production" (N2Africa Phase II Proposal, pg. 9). To remedy this, N2Africa revised its strategy for delivering technologies in Phase II to include direct engagement with value chain actors through the creation of PPPs.

N2Africa Phase II: As in Phase I, the project hosted ToTs for 9,016 partner staff and extension agents (30% of whom were women) in six core areas: good agricultural practices in legume production, protocols for dissemination of BNF technologies, appropriate input/output marketing models and strategies, appropriate data collection for feedback/leaning, business entrepreneurship/group dynamics, and processing and value addition. The project also conducted "step-down" trainings for 61,401 value chain actors in seed production, good agricultural practices, and other topics not listed, with the intention of a legacy of national-level expertise in legume production (N2Africa Annual Report 2019, pg. 14).

N2Africa focused on scaling partnerships during Phase II and viewed PPPs as key to project implementation. During Phase II, N2Africa established a total of 257 PPPs in five key areas: research, capacity building, input supply, output markets, and technology dissemination.

Coordinating across countries created a number of challenges, including synching the timing of project roll-out across multiple countries with differing cropping seasons, and requiring a large number of partners to work within each country. Somewhat paradoxically, having a large number of partners resulted in a more "standardized approach to dissemination" strategies rather than context-specific ones, as the project had originally intended. (2009-2013 Final Report, pg. 101-102). The project transitioned to more-decentralized planning for Phase II.

Results Tracking Data

To strengthen the capacity of partners to use N2Africa's legume technologies and approaches, the grantee aimed to provide trainings to at least 320 partner staff[19] **(Results Tracker 1.4)**. Since its start in 2014, N2Africa engaged a total of 9,016 partner staff in training of trainers sessions to build the capacity of partners, including extension agents.

Enable learning and assess impacts at scale: Besides the implementation of an M&E framework to track progress and guide planning activities **(Results Tracker 5.1)**, and conducting an impact evaluation **(Results Tracker 5.7.1)**, N2Africa also aimed to have dissemination partners integrate dissemination approaches into their programs to enable their target users to learn **(Results Tracker 5.2)**. As N2Africa worked with 257 partners who used dissemination approaches to a varying degree, the project well exceeded the target (16 partners). Dissemination approaches included those that reached a large number of farmers but provided fewer learning opportunities (e.g., radio), and those that had limited coverage but were better suited for learning (e.g., demonstration days).

To increase knowledge of and access to household-level legume processing tools and improve the nutritional status of women and children **(Results Tracker 3.3)**, N2Africa implemented

[19] Target outcome 1.4 in the Results Framework 2019 reads "By Q4 of year 5, at least 320 partners trained in N2Africa technologies and approaches." However, the indicator refers to "number of persons trained," and thus the target outcome should have referred to "partner staff" instead of "partners."

campaigns and provided trainings on legume processing tools, and sensitized farming communities on the nutritional values of various legumes. Since 2014, more than 13,000 women have been exposed to approaches to processing various products (e.g., soybean milk, groundnut oil) and using legume technologies. While N2Africa far exceeded their target (5,000 women), monitoring data does not report on the extent to which knowledge of and access to legume processing tools improved.

Project strategy, implementation, and capacity strengthening: PPPs played a key role in N2Africa's project strategy and its approach to coordination, implementation and capacity strengthening activities. Active collaboration with PPPs along the legume input and output value chains was therefore an integral part of the grant's project strategy to achieve its overall goals **(Results Tracker 1.3)**. With 43 active partnerships supporting the implementation of activities by the end of the project, N2Africa exceeded its target (32 partnerships). Of these partnerships, over 60% were involved in the development of input and output markets, and more than 50% supported dissemination and capacity-building activities. Similarly, with 11 inoculant outlets selling inoculants, the grantee also exceeded its target of making inoculants available through PPPs, importation, and local production **(Results Tracker 2.5.1)**.

Dissemination, sustainable input supply, and market access: To track the grantee's success in delivering and disseminating legume technologies to farmers, N2Africa monitored the number of farmers reached **(Results Tracker 2.2**). N2Africa reported that it reached 660,198 farmers (45% women) through dissemination partners, which exceeded its target (555,000 farmers). Its success in reaching a large number of farmers relied on using a mix of dissemination approaches (**Results Tracker 5.2**).

In-Depth Interview Results

Interviewees commented that the PPP established in Ethiopia were critical for scalability. For example, challenges with the undeveloped seed market in Ethiopia were improved through PPP. By involving the government through land used at its research stations and working with farmer groups to monitor seed quality and production, the legume crop was expanded and farmer groups had seeds for future generations. Government partners were also critical for scaling as they were able to disseminate information on a large scale.

On-Line Survey Results

The overwhelming majority of online survey respondents either strongly agreed (7 of 10, 35%) or agreed (10 of 20, 50%) that N2Africa strengthened the capacity of extension agents to disseminate and promote new farmer technologies and tools. Respondents also identified how to improve extension agents' capacities through the following top three ways: 90% (18 of 20) recommended involving private sector partners with more-relevant business models, 80 %(16 of 20) recommended increasing linkages to input distributors, and 70% (14 of 20) recommended increasing training on tools they are disseminating and promoting.

Summary and Main Lessons Learned for Scaling

The project held numerous activities as part of its scaling work, including trainings and training of trainers' sessions; and collaborations with farmer groups, NGOs, agro-dealers, partner staff and extension agents.

N2Africa focused on scaling partnerships during Phase II and viewed PPPs as key to project implementation. The large number of partners both helped and hampered the project; while the number of partners allowed Phase I to have wide reach, it also made coordinated efforts difficult

to execute. Several data sources point to the PPPs for having a key role in N2Africa's project strategy and its approach to coordination, implementation and capacity-strengthening activities.

Policy Development, Institutionalization, and Sustainability

N2Africa's approach to ensuring longer-term adoption of their research, agronomy solutions, and tools, including plans to institutionalize their work through local stakeholders and institutions

Document Review

N2Africa was involved in developing a national inoculants policy in Ethiopia, and helped develop a biofertilizer policy, which, as of the 2019 Annual Report, had yet to be endorsed by the government. Also, in 2019, N2Africa developed policy recommendations for Tanzania and Ethiopia after consultations with stakeholders, including a 10-point policy recommendation for the legume value chain, addressing areas such as production, extension, co-ops, consumption, markets and government institutions.

The sustainability of N2Africa's extensive agronomy research activities and introduction of legume technologies relied primarily on a market systems approach focused on creating a functioning supply chain by building PPPs that link farmer cooperatives to agro-dealers, processors, and fertilizer or seed companies. While N2Africa increased awareness of and demand for legume technologies (e.g., rhizobial inoculants), building a sustainable market and supply chain to drive technology adoption was difficult (2009-2013 Final Report), which is why Phase II focused more specifically on this aspect of the work.

Sustainability of the partnerships hinges on tangible benefits from the legume technologies. As proof of these benefits, several respondents noted that N2Africa was able to steadily increase awareness of and demand for inoculants across focus countries. A study conducted to evaluate the impact of N2Africa's technologies on farmers in Ethiopia showed that inoculants (bundled with improved legume varieties or fertilizer) led to an adoption rate of between 15 and 30%. While this was promising, farmers were often unable to accurately quantify their needs, or lacked the communications channels to ensure agro-dealers were aware of the inputs needed. Especially in the case of inoculants, agro-dealers were wary of stocking inoculants owing to the limited shelf life.

On the supply side, N2Africa faced nascent local markets and small-scale production of inoculants. As manufacturing inoculants is a low-value and low-margin business, local producers are often not competitive with international manufacturers. Hence, most inoculants were imported. Creating a market for inoculants by linking importers to distributers, agro-dealers, and farmers was challenging, not least because the effectiveness of inoculants decreases without cooled transportation and storage solutions. Despite N2Africa's achievements in building awareness and use of inoculants by smallholder farmers, and a reported increase in interest from the private sector, some interview respondents from the project's impact study were not certain that the momentum and progress made with developing supply chains would be sustained.

External factors were also reported to affect sustainability. Price volatility in Ghana, for example, complicated N2Africa's efforts to build a market for its legume technologies, according to several interview respondents. They referred to instances where a collapse in word market soybean prices forced local soybean prices to drop, discouraging local production and therefore demand for inputs (N2Africa 2019, p.59).

The policy and regulatory environment also posed challenges to achieving sustainability. N2Africa staff respondent noted that inoculants were not registered in some of the grantee's focus countries at the start of the project, and that this lack of regulation initially limited their inoculant activities. Similarly, the grantee also faced a temporary lack of demand for soybean in Tanzania as a result of the government instituting a value-added tax on animal feeds (N2Africa 2019, p.59). In Ghana, however, N2Africa supported advocacy efforts that led to inclusion of a new fertilizer blend into the country's subsidy program (N2Africa 2019, p.54).

Results Tracking Data

N2Africa helped inoculant producers avail themselves of improved inoculant formulations for legumes with the aim of increasing legume productivity by 10% **(Results Tracker 4.2)**. The grantee met its target to have 3 inoculant producers use the improved inoculant formulations. N2Africa refers to target outcome 4.1 for evidence on productivity increases.[20]

In-Depth Interviews

Close working relationships between N2Africa country coordinators and government officials led to development of legislation supporting use of inoculants in countries where they had not been previously approved. These N2Africa partnerships were critical for the project and led to lasting change.

Respondents discussed the dedication of people—specifically the difference with the design of the overall project staffing. The N2Africa project maintained a small core group of grantee staff and focused resources on the involvement of the stakeholders (farmers, sellers, brokers, policymakers, etc.) most affected by the work. The project focused on developing PPPs with the aim of bolstering take-up of the technology while increasing the opportunity to sustain use of the technology when the project concluded.

Summary and Main Lessons Learned for Policy Development, Institutionalization, and Sustainability

N2Africa influenced policy in some of the participating countries. The project was involved in developing a national inoculants policy in Ethiopia and helped develop a biofertilizer policy, for which the final status was still pending at the end of the project. N2Africa also developed policy recommendations for Tanzania and Ethiopia after consultations with stakeholders.

N2Africa partnerships were critical for the project and led to lasting change. For example, the sustainability of N2Africa's agronomy research activities and introduction of legume technologies relied primarily on a market systems approach focused on creating a functioning supply chain by building PPPs that link farmer cooperatives to agro-dealers and other partners.

Close working relationships established between N2Africa country coordinators and government officials led to development of legislation supporting use of inoculants in countries where they had not been previously approved during the project. These relationships could be sustained beyond the project. However, the outcome of the legislative activities is unknown.

Policy and regulatory concerns also were expected to be challenges to sustainability. Inoculants were not registered in some of the grantee's focus countries at the start of the project, and this

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[20] The impact evaluation defined adopters as having used at least three N2Africa technologies. Data on productivity does not disaggregate by technology type but shows productivity increases for "adopters" compared to "non-adopters."

initial lack of regulation presented serious implementation barriers. For example, advocacy around inoculants and fertilizers was ongoing in some of the N2Africa countries like Tanzania.

Towards the goal of empowering women, N2Africa surpassed its target to engage 5,000 women, but was not able to measure their potential improvements in knowledge and access to household-level legume processing tools, nor changes in nutritional status of women and children. This is a missed opportunity in assessing N2Africa's institutionalization or sustainability of project goals.

Impacts

N2Africa developed agronomy solutions adopted by women and other farmers, including inoculants which increased farmers' productivity, and strengthened supply chains.

Document Review

N2Africa Phase I

Phase I focused on three main BNF technologies: fertilizers, seeds, and inoculants. Overall, adoption rates for Phase I technologies were low, and with a few strong exceptions (Kenya and Nigeria), a majority of farmers surveyed in N2Africa's Early Impact Assessment were non-adopters. The most gains were made in soybean production, given its commercial value and the support by external actors (outside of N2Africa) to build soybean value chains within Africa.

The grantee found that despite the success in reaching farmers, the project sometimes achieved less than full uptake because of problems with input supply (due to absence of supply chains), market access and farmers' purchasing power (lack of cash to invest in inputs), and the risk associated with variable response to technologies.

While N2Africa had one of the most detailed processes in place for measuring outcomes and targets compared to the other grant projects in the portfolio, they still encountered M&E challenges. The final report noted that faulty baseline calculations inhibited the project's ability to accurately measure outcomes, in part because the baseline yields were somewhat greater (14%) than the figures used in the original calculations.

N2Africa Phase II

During Phase II, the project created 32 companies/businesses across the different countries of the grant project, engaged 660,198 households in legume intensification, and engaged 176,910 households in collective marketing and value addition of legume grains.

Towards the end of the Phase II grant project, N2Africa conducted a large-scale impact evaluation survey in Ethiopia, Ghana, Borno (Nigeria), Nigeria, Tanzania, and Uganda. In total, the survey sampled 3,744 farmer households, 49.4% of which formed the treatment group (i.e., households who received direct support by the project) and the remainder formed the non-treated group.

The evaluation sought to address farmer productivity and adoption of improved legume germplasm (e.g., bush bean, climbing bean, cowpea, fava bean, chickpea, groundnut and soybean); inorganic fertilizer and organic amendments; inoculant; and best agronomic practices (e.g., legume rotation with other crops, intercropping of legumes with other crops, weed

management, row planting). [21] Findings from the impact evaluation showed that adoption of the legume technologies promoted by N2Africa increased among households exposed to the grantee's activities. The adoption of N2Africa's legume technologies among households who participated in the grantee's activities was significantly higher compared with among households who did not participate, especially in Ghana and Borno. This finding indicates that the approach of N2Africa helped to improve access to legume technologies. Furthermore, the evaluation shows a significant increase in the Household Dietary Diversity Score of adopters of legume technologies compared with non-adopters, which indicates improvements in nutritional status. The evaluation did not find gender difference in nutritional status. Results from 744 households in Ethiopia found that within the group that received direct project support, a combination of improved legume varieties and inoculant had the highest rate of adoption (28.1%), followed by fertilizer and inoculant (16.9%). Among adopters, legume productivity increased by 83.5 kg/ha. In total, income generated from all crop sales increased by $166.

The impact evaluation also measured the productivity increase in terms of yield per hectare. The impact evaluation found demonstrable productivity increases among adopters of the legume technologies, with the highest impact in Uganda (244 kg/ha) and the lowest productivity increase in Ghana (51 kg/ha).

For fertilizer sold, the project discovered significant challenges in accessing improved inputs. . Yield gain and/or market access were not sufficient for all farmers to justify the high cost of fertilizer.

The grantee also only partially met its target (64% of target reached) of households engaged in the collective marketing and value addition of legume grains and value-added products. However, these grant projects were agronomy-focused rather than agriculture/marketing-focused.

A major component of N2Africa's Phase II work was integrating women in all aspects of the project, from field demonstrations to student support to beneficiaries of technologies, particularly labor-saving tools. According to N2Africa, legumes are considered "women's crops," presumably meaning they are often tended to by women but that improved inputs and technologies are often most accessed by men. The project did not meet its targets for women using labor-saving tools. Limited access to labor-savings tools, the upfront costs, or tools that did not meet smallholder requirements were the main reasons this target was not met (N2Africa Annual Report, 2019).

[21] On page 23 of the 2019 Annual Report, an *adopter* is defined as "having used at least three N2Africa technologies, improved practices, and inputs," whereas page 25 defines an adopter as a "household ... [who] for three seasons ... uses at least two of the N2Africa technology components."

Results Tracker

N2Africa's monitoring data shows it met most of its targets. Of the targets reported in the RT, N2Africa exceeded or met about 75% of the targets, 12% of the targets were partially met, and for a few targets the grantee did not report on the achievement or the achievement was not specific enough. N2Africa, did not report on most of the targets that were defined in the RF.

Table B7. Results framework for N2Africa Phase II

	Target exceeded	Target met	Target not met	Target/actual lacks cl	Target/actual missing	Grand Total
1. Project strategy, implementation, and capacity building	**2**	**3**				**5**
1.3. Partner cooperation along legume value chain	1					
1.4. At least 320 partners trained in N2Africa technologies and approaches	1	1				
1.5. Young African professionals with increased expertise in nitrogen fixation		1				
1.6 Researchers/scientists are empowered to further N2Africa's R&D		1				
2. Dissemination, sustainable input supply, and market access	**2**	**1**	**2**			**5**
2.2. Dissemination partners reach anticipated number of households targeted		1				
2.3. Agro-dealers market fertilizer, seed, and inoculants	1		1			
2.4. Households engaged in collective marketing and value addition			1			
2.5.1. Inoculants available through PPPs, importation, or local production	1					
3. Empower women to increase benefits from legume production	**2**	**1**	**1**		**1**	**5**
3.2. Improved income for women from legume production	1				1	
3.3. Access to legume technologies improves nutritional status	1					
3.4. Women's use of labour-saving tools resulting in higher profits		1	1			
4. Tailor and adapt legume technologies to close yield gaps	**3**	**1**		**1**		**5**
4.1. Legume production recommendations results in >50% productivity increase	2					
4.2. Improved inoculant formulations result in >10% productivity increas		1				
4.6.2. Elite strains used for inoculant production				1		
4.8.1. SOP's used by inoculant producers and retailers	1					
5. Enable learning and assess impacts at scale	**1**	**3**			**1**	**5**
5.1. Strategic M&E framework provides timely feedback to learning		1				
5.2. Integration of dissemination approaches for legume technologies	1					
5.3. Effective ICT tools provide information on legume production					1	
5.5.1 Enable learning and assess impacts at scale		1				
5.7.1. Sustainability of legume interventions for smallholder farmers evaluated		1				
Total	**10** (40%)	**9** (36%)	**3** (12%)	**1** (4%)	**2** (8%)	**25**

Dissemination, sustainable input supply, and market access: Last-mile service delivery with local agro-dealers marketing fertilizer, seeds, and inoculants was key to the delivery of a sustainable supply of inputs (**Results Tracker 2.3**). The grantee did not meet its target to increase the sales of seeds, fertilizer, and inoculants through agro-dealers and to increase the use of these inputs by producers groups. N2Africa reached 62% of the target for seed sales and use (6,660 tons), and 54% of the target for fertilizer use and sales (11,100 tons), but exceeded its target for sales and use of inoculants (56 tons).

N2Africa also engaged farmer households in collective marketing of legume grains and value-added products (**Results Tracker 2.4**). Despite engaging nearly 177,000 farmers in collective marketing, the grantee did not reach its target (275,000). N2Africa's Annual Report (2019) states

that several factors limited the number of farmers that could be engaged; these included low market prices due to quality, limited storage, and non-acceptance of some varieties, as well as transportation costs.

Empower women to increase benefits from legume production: To track the extent to which women improved their income from legume production and increased their say in the use of income (**Results Tracker 3.2**), N2Africa monitored the number of women who established small businesses centered around legume processing tools. A total of 32 women-led business across core countries were established, which exceeded the target of 10 businesses established by women. Although the grantee's monitoring data does not include information on the extent to which women increased their income, findings from the impact evaluation shows that productivity gains resulting from the adoption of technologies promoted by N2Africa increased income in the grantee's core countries. N2Africa's Annual Report (2019) states that women who adopted these technologies benefitted in most countries equally in terms of income and productivity gains, as compared to their male counterparts. It also finds that women sold a larger share of their produce than men. While these results may indicate improved income for women from legume production, no data is presented on the extent that women's influence on the use of income has improved.

N2Africa promoted labor-saving tools, especially for women, with the aim to increase higher net profits from legume production and processing (**Results Tracker 3.4**). While large numbers of women were using threshers and herbicides as major labor-saving tools in 2019, the target was not achieved.

Tailor and adapt legume technologies to close yield gaps: To close legume yield gaps, N2Africa provided farmers with recommendations for the intensification of legume production, with the target to at least increase legume productivity by 50% (**Results Tracker 4.1**). Monitoring data indicates that this target was met, as 365,850 farmers increased their productivity by 50% through adaptation trials, well above the target (275,000 farmers).

In-Depth Interviews

Respondents generally stated the most important outcomes of the N2Africa project as increased legume crop yield (both quality and quantity); the creation of linkages between the private and public sectors with the producers; and the change in how smallholder farmers plant, grow and harvest their crops.

Inoculant technology was planned for use since the beginning of N2Africa and supported the achievement of these outcomes. The project coordinator estimated inoculant demand and inoculant popularity had risen 17-fold in sale, in use and in demand. As a result of N2Africa, legumes like soybeans and chickpeas began trading on the government's commodity exchange. However, demand for the inoculants created a challenge in being able to supply them during and after the project.

Some respondents felt that partnership was one of the most important N2Africa activities for achieving results, and considered stakeholder involvement through the public-private approach as a "great way of making sure you have good outcomes" (N2Africa staff). Partnerships were found to be beneficial for people on the value chain, like smallholders, private partners (e.g., inoculant producers), individual traders, and cooperatives, and they were critical for scalability in Ethiopia.

The project fell short on its goal to empower or involve women in legume production technology. The main examples of empowerment provided by respondents included women's improved knowledge of nutrition from project trainings, and women's preparing meals using soybeans and chickpeas to increase nutritional value of meals. Fewer examples of women's empowerment existed throughout the newly created legume value chain in Ethiopia in which women specifically benefitted financially. Interviewees reported on challenges such as women's low levels of participation in project activities like training, use of tools and more-complex crops (i.e., soybeans) and marketing mainstreaming of soybeans. In addition, gender roles also influenced women's involvement in activities like field visits and farm activities where women were invited by the male head of household.

Summary and Main Lessons Learned for N2Africa Impacts

The main lesson learned from N2Africa with respect to impact is that progress toward diverse goals may be achieved despite challenges. Many key outcomes were met, and gains were made, in reaching large numbers of households and smallholder farmers and other populations like researchers or students and project partners. However, some goals and impacts were harder to achieve. While inoculants' sales surpassed their targets, the project faced barriers to fertilizer sales attributed to cost barriers for farmers with small plots who couldn't justify the cost.

N2Africa's monitoring data show the project met or exceeded most of its Phase II targets. The project was especially able to meet targets related to project strategy, implementation and capacity building. This finding is consistent with the engagement of partners in a range of activities including PPPs. PPPs also contributed to other outcomes like improved access to inoculants; however, meeting outcomes for adoption of technology was a bit more difficult even when successful. Inoculant demand increased but the supply was not consistent.

There were mixed evaluation results on the project's success with engaging and empowering women farmers. Survey results showed high levels of engagement with farmers overall, while mixed results were reported in the surveys and interviews on whether the project was successful in involving or empowering women farmers in particular. Some project data point to success, with women establishing more than the goal of 10 businesses, and the fact that women who adopted technologies promoted by N2Africa benefited in most of the project countries in terms of income and productivity gains compared to males. Still, social influences such as the role of gender and women's agency in relation to a male head of household were barriers to women's empowerment, and data regarding women's influence on how income is used were not presented. What is clear is that the project was able to engage women, and women experienced some benefits, but some successes may have been less than what was targeted or not recorded well enough to ascertain.

B3: SBPEA Summary

This chapter summarizes the data collected for the Sustainable Banana Production in East Africa (SBPEA) grant project and, based on the data collected, provides lessons learned from the SBPEA grant project's implementation. The chapter starts with a brief description of the grant project. Sections reflecting different parts of the Agronomy Grants Framework follow (the chapters of the main report body also follow this structure). For each of these sections, we present the data from up to four different sources (document review, review of the results trackers, in-depth interviews with grantees and stakeholders, and the on-line survey with grantee stakeholders; not all data sources are available for all parts of the framework). Each section concludes with a sub-section on lessons learned. The introduction to the appendices provides definitions and content for each of the sections of this chapter.

List of Acronyms

BXW	Banana Xanthomonas Wilt disease
DST	Decision-support tools
IITA	International Institute of Tropical Agriculture
ISFPM	Integrated Soil Fertility and Pest Management
MLE	Monitoring, learning and evaluation
NARL	National Agricultural Research Laboratories (Uganda)
NARO	National Agricultural Research Organization (Uganda)
TARI	Tanzania Agricultural Research Institute

Narrative Description of SBPEA's Activities

Banana is an important crop in East Africa, providing both income and food for over 50 million people in the region. However, a combination of constraints – including pests, disease, drought, and low-nutrient soils – constrict productivity, resulting in yields significantly lower (~70%) than their maximum potential. While addressing these constraints is crucial for intensifying banana production, mitigations differ depending on site. For instance, pest damage can vary according to soil nutrients, and the profitability of fertilizer use depends on proximity to markets (2015 Proposal, pg. 4). Therefore, closing yield gaps requires addressing a multitude of factors and producing context- and location-specific recommendations, aka *best-fit agricultural practices*.

The Sustainable Banana Productivity in East Africa (SBPEA), a $5.7million project led by the National Agricultural Research Laboratories (Uganda) from September 2016-July 2020, seeks to improve productivity and sustainability of banana-based systems through four key interventions. The project is currently in its final stage, and as of the most recent reports made available (2019 Progress Narrative), much work remained to be completed. However, a brief summary of completed and anticipated work is provided here:

1. **Integrated Soil Fertility and Pest Management (ISFPM):** a key objective of SBPEA is to provide farmers with the tools and knowledge of how best to improve both soil fertility and pest management. A number of activities supported this goal: SBPEA conducted choice experiments with Ugandan farmers to better understand how they make decisions around

fertilization and pest management; SBPEA established field trials to understand the efficacy of different types of fertilizer – especially silicon fertilizer – on different types of soils; SBPEA conducted research on how bananas recover from a common wilt infection (banana Xanthomonas wilt [BXW]) and how to improve residue management for weevil control; SBPEA established a 4-step ISFPM improvement prototype for farmers to follow depending on their access to inputs and labor. Demonstration plots were established in both Uganda and Tanzania to allow for project coordinators to "show" rather than "tell" farmers best practices, and to allow farmers to participate in the process. The project recorded productivity gains in sites across Uganda and Tanzania, though a spreadsheet of productivity over time and listed by site would be more helpful in understanding medium term impacts of the project.

2. **Development of decision-making tools:** data gathered from ISFPM activities are informing the development of decision-making tools. As of the 2019 narrative report, tools are still in development. The team planned to develop five tools to improve farmer productivity by focusing on key aspects of banana production. Two of these five that are already developed include planting density (one for bananas as a sole crop and one for banana-coffee intercropping) and nutrient input management for sole crop bananas. Residue management for weevil control is still under development, and single disease stem removal is behind schedule due to low prevalence of the disease in target communities. The mobile device application (mobile DST app) for optimizing fertilizer use is also still under development. The grantee dropped the development of the staggered sucker selection tool because farmers deemed it too risky for to test in their fields.
3. **Farmer-friendly training and communication tools**: In addition to decision-making tools, SBPEA also developed easy-to-distribute tools such as material hand-outs, radio broadcasts and posters in both Uganda and Tanzania. In Uganda, radio campaigns included a number of questions they asked farmers to text in responses to. This provided a way for project officials to gain data on farmer priorities over a large population; SBPEA notes that 20,525 Ugandan texted responses to radio poll questions.
4. **Enhanced capacity of national research institutions to conduct agronomy research:** SBPEA worked with national research institutions in both Uganda and Tanzania to develop communications materials, and to provide officers (n= 52; Uganda= 22, Tanzania =30) with access to training in GIS mapping, statistics, farming systems, banana agronomy, digital data management and more.

Needs and Demand

How SBPEA identified agronomy research needs, the users of the research, and how they prioritized the agronomy research needs.

Document Review

During the first year of the grant project, SBPEA conducted a baseline survey, identified existing research gaps, and consulted with various stakeholders and farmers to assess specific needs and desired outcomes in Uganda. The team identified the following use cases: "intercropping, integrated soil fertility and pest management, optimum planting density, residue management for weevil control, banana fertilizer optimizer, single diseased stem removal for BXW management and staggered sucker selection." (2017 Progress Narrative, pg. 7).

Use-cases were prioritized mainly from data gathered in Uganda; baseline survey results for Tanzania were not published until the second reporting period (2018 Progress Narrative, pg. 2).

SBPEA's primary target users were smallholder banana farmers and farmer groups in Uganda and Tanzania. Secondary target users include national- and district-level government institutions and private sector stakeholders.

Initial needs were identified in the original project proposal and then cross-checked during consultative meetings with scaling agents during the first project period. A number of needs were identified, from poor infrastructure to pests and disease to climatic constraints to prices. In total, more needs were identified than what could be realistically covered by the project. Table B8 lists the needs that constituted the core of SBPEA's focus.

Table B8. SBPEA: Target user needs

Need identified	Target user category
Rampant pest and disease infection, with an emphasis on weevils and BXW.	Farmers
Lower than hypothetically attainable yields	Farmers
Increased capacity of national agricultural agencies, especially to conduct research.	Public research institutions

In-Depth Interview Results

SBPEA initially included seven use cases in the proposal that focused broadly on integrated soil fertility and pest management with the use cases being a subset of this focus, based on 20 years of in-country banana research, and by using a literature review, baseline survey and analysis of where there were gaps in agronomic research and technologies. After grant approval, the grantee conducted initial workshops at each action site where stakeholders ranked constraints and prioritized interventions.

The grant focused on a "stepwise intensification" approach by using an integrated system of different agronomic practices and tried to determine the combination of practices needed to optimize production while simultaneously minimizing the cost of application and cost of inputs (cost to farmers of implementing the practices). Then the system built on what farmers were able to afford to what they could increasingly be able to afford as production increased.

> *Because when we went in with a mindset of what we had proposed the Foundation to do, from the assessment somehow we realized that the farmers had also their priorities that we had to address first.*
>
> \- SBPEA Stakeholder

Initial meetings with farmers grouped them into different categories – A, B, C, D – based on income, region, resources, size of landholding, and current use of recommended agronomic practices. Agronomic practices were then targeted to the specific needs of each farmer "group". While the goal was to have comprehensive soil, water and pest management practices implemented, farmers started implementing different practices depending on their "grouping".

Through this process SBPEA was able to identify the needs of farmers, who were often identified by grantee respondents as the target user for the research. Other respondents also identified scaling agents, extension workers, and researchers as target users for the research.

On-Line Survey Results

The respondents to the on-line interview generally reflected the responses from interview respondents.

Eighty-five percent (17 of 20) of survey respondents reported that SBPEA prioritized their research based on the needs of beneficiaries, with 75 percent reporting that SBPEA prioritized research based on agronomic constraints that limited productivity (15 of 20), and 60 percent (12 of 20) reported that SBPEA prioritized research based on the expertise of the research team. These answers appear to reflect the multiple inputs used in the needs assessment conducted by SBPEA, that is, the needs assessment included as criteria an analysis of the potential benefit to farmers, the potential constraints on agronomy solutions for farmers, and considerations of the existing expertise of the research institute.

Sixty percent (12 of 20) of on-line respondents responded that they thought SBPEA had a good understanding of how to assess if there was demand for the research, while 30 percent (6 of 20), thought there was only an average understanding of how to assess if there was demand for the research. These results may reflect stakeholder views of who the target users were, and that the grant project did not fully assess the demands of all types of target users.

Respondents to the on-line survey primarily identified smallholder farmers (19 of 20, or 95%), agricultural extension agents (18 of 20, or 90%), medium scale farmers (17 of 20, or 85%), and academic agronomists/scientists/researchers (14 of 20, or 70%) as the main target users for the grant project's research. The majority of respondents felt that some of the needs of target users were met.

Summary of Main Lessons Learned on Needs and Demand for Research

SBPEA was able to apply lessons learned about demand and research to other parts of the Agronomy Grants Framework. The grantee's approach to needs assessments, determining research activities and prioritizing research technologies by including farmers as key partners appeared to have an important role in later parts of the framework – by targeting research technologies by region and by grouping farmers into categories based on income, resources, region, size of plots, and experience with agronomic practices, the grantee could develop research and agronomy solutions to meet the need of each farmer.

Interview respondents made little mention of how the grant project assessed demand for digital technologies, such as decision-support tools (DST) apps, making it difficult to know if farmers were driving the demand for these types of digital applications.

Development

SBPEA's efforts to improve the capacity of researchers to undertake banana agronomy research and development, research undertaken, and tailored agronomy solutions developed.

Document Review

SBPEA theorizes that despite a number of available technologies, "farmers continue to use unsustainable agricultural practices, thus the persistent occurrence of production challenges and problems" (2017 Progress Narrative, pg. 8). To address this, SBPEA is developing 'hybrid' approaches—using organic and inorganic materials—to manage pests and soil fertility. However, this is not straightforward; the management of pests and soil fertility involves a number of trade-offs that are often context-specific.

To understand these tradeoffs and synergies, SBPEA undertook a number of projects to develop guides—and eventually plans for decision support tools—on best **ISFPM** practices. These activities included (but are not limited to): research on current soil fertility and pest management practices (which revealed that 70 percent of Ugandan farmers actively undertake soil fertility and pest management practices, 2017 Progress Report, pg. 3); choice experiments with Ugandan farmers to better understand how they make decisions around fertilization and pest management; field trials to understand the efficacy of different types of fertilizer – especially silicon fertilizer – on different types of soils; research on how bananas recover from BXW and how to improve residue management for weevil control; development of a 4-step ISFPM improvement prototype for farmers to follow depending on their access to inputs and labor (2019 Progress Narrative, pg. 6); and analysis of data from "use cases on intercropping, ISFPM, staggered sucker selection and residue management" (2019 Progress Narrative, pg. 20).

Implemented residue management for weevil control: The initial baseline survey and consultations with stakeholders revealed that mulching—while helpful for maintaining soil retention, residue, and assisting banana growth—can also provide a breeding ground for weevils. SBPEA thus set out to establish optimum mulching and banana management interventions that retained soil residue *and* reduced weevil breeding opportunities. Three types of interventions underscore SBPEA's work in weevil controls: agronomic practices, the development of a DST, and the dissemination of weevil-resistant banana hybrids.

In the first reporting period (2016-2017), SBPEA used data gathered from baseline observations and previously published research to compile a list of interventions on how farmers with low to very heavy weevil damage could mitigate weevil infestation while retaining adequate residue (2017 Progress Narrative, pg. 8). In the second reporting period (2017-2018), SPBEA set up demonstration plots across three sites in Uganda where they exhibited different *agronomic practices* such as mulching and manure application. From these demos, SBPEA reported an "observed improvement in crop residues to minimize weevil damage" (2018 Progress Narrative, pg. 15). In this same reporting period, SPBEA decided to *develop DSTs* for the areas identified in the initial project period, including weevil control. In the third reporting period, SBPEA reported that, "further development of these decision support tools awaits data from ongoing water by potassium by silicon against weevil damage and yield gap trials" (2019 Progress Narrative, pg. 2). SBPEA noted that they secured a supplier for liquid silicon fertilizer that they would test in the fourth reporting period (2019-2020). SBPEA established 160 DST validation trials to be completed in August 2020 (MLE Report Period 4, pg. 21-22).

Implemented BXW disease control: BXW is a bacterial disease that can destroy banana trees. Since the beginning, the project has focused on addressing BXW, and a DST specifically for BXW is being designed. However, it is unclear from documents how SBPEA disseminated information on managing BXW. Based on evaluation reports, we know BXW has been included in workflows. The grantee clarified that the project was run by Makerere University, but because it focused on bananas in Uganda, the foundation requested that SBPEA manage the project as part of its banana agronomy work. This is likely the reason for the lack of clarity on the integration of the project activities from documents. The Monitoring, Evaluation, and Learning (MLE) Report for the third period found that most farmers in Uganda were already addressing BXW given the prevalence of the disease over the prior two decades (MLE Report Period 3, pg. 20). The situation was flipped in Tanzania, where farmers began deploying disease control practices only after interacting with SBPEA (MLE Report Period 3, pg. 21).

Results Tracking Data

To be able to provide site-specific recommendations, SBPEA needed to integrate geospatial information needs into DSTs **(Results Framework 1.2)**. SBPEA, therefore, developed banana cropping system spatial distributions and socio-economic and biophysical recommendation domains by 2018, meeting its targets. Part of SBPEA's research focused on unraveling mechanisms of banana plant recovery from BXW to inform Single Disease Stem Removal (removal of symptomatic plants only) **(Results Framework 1.3)**. The grant has nearly completed these activities with the development of two protocols for determining mechanisms of recovery from BXW and research completed on presence and defense responses to pathogens, but some repeat experiments are still pending.

To continue innovative agronomy research at NARS, SBPEA set the target to have at least five research scientists skilled in conducting agronomy research **(Results Framework 3.1)**. The project conducted a number of trainings and workshops to equip research scientists with the necessary knowledge and skills in statistics, geospatial analysis, and banana agronomy basics and farming systems analysis. Apart from some trainings and workshops that were yet to be conducted, the grant met most of its targets by training 52 scientists, involving 17 staff at the National Agricultural Research Organization (NARO) and ARI directly in project implementation activities, and establishing a banana agronomy repository.

In-Depth Interview Results

Project research was ongoing and as research technologies were developed they were disseminated to the scaling agents and local partners. However, bananas are a perennial crop and the time it took to develop and verify the research was at least three growing seasons, which for certain technologies that rely on field based data, such as the DSTs, delayed the work in these use cases.

On-Line Survey Results

The vast majority (90%) of online respondents either strongly agreed (11 of 19, or 58%) or agreed (6 of 19, or 32%) with the statement that SBPEA strengthened research systems capacity.

Survey respondents overwhelmingly felt that a key change the grant project could make to strengthen the capacity of agricultural researchers was increased opportunities for learning exchanges (18 of 19, 95%), followed equally by additional training in research and analysis (17 of 19, 89%) and improved collaboration with key research institutes (17 of 19, 89%).

Summary and Main Lessons Learned on Development

A key piece of the development work for SBPEA were its activities to help build capacity for R&D by training research scientists and graduate students in agronomy in both Uganda and Tanzania. The foundation directly funded NARO, the only grant project in this portfolio where a government research institute was the main funded entity, which allowed for direct involvement of an experienced research facility and scientists in agronomy research. NARO and its research scientists already had extensive experience in banana research and were able to build upon the existing research infrastructure for this grant project.

Despite this experience, research and field trials needed more time than expected, which delayed the development of tailored agronomy solutions. Bananas needed at least three growing seasons to develop and verify the research and conduct field trials, and with a single-phase five year grant, this limited the time available for other steps in the framework – scaling and dissemination

of agronomy solutions. This delay was a particular issue for the research needed to develop digital DSTs, which was still not completed at the time of this assessment.

Due to the work in assessing needs and demand as described in the previous chapter, SBPEA was able to conduct transformative research and develop solutions that were tailored to the needs of each individual farmers. The grant project's work to bundle soil, pest and disease management techniques built off of existing in-country methods and solutions, and were already familiar or at least known to many farmers, potentially making them more easily accepted.

Scaling

SBPEA's approach to scaling agronomy solutions, including dissemination of agronomy solutions and building the capacity of local scaling partners and extension officers to scale or disseminate agronomy solutions.

Document Review

In 2019-2020, SBPEA promoted four weevil-tolerant hybrid varieties of bananas and held "sensitization workshops" for stakeholders ("Farmers, commercial seed multipliers, scaling agents, local leaders and representatives of the respective district production departments" [MLE Report_Period 4, pg. 8]) at the three Ugandan project sites. SBPEA's dissemination plan for these varieties had a holistic design (using farmers, private and public sector stakeholders to disseminate varieties).

In total, the recipients of the disseminated varieties included 124 farmers, 10 seed multipliers and four institutions. Each farmer received 60 suckers and were mandated to produce and give out at least two suckers from each cultivar to another farmer in their group. The commercial seed multipliers received more plantlets than those received by individual farmers and institutions. The seed multipliers were mandated to establish mother gardens from which they would multiply and sell seed to those in need. (MLE Report Period 4, pg. 8-9).

SBPEA held meetings in Uganda to "sensitize" farmers and scaling agents on the use of inorganic fertilizer, demonstrate the cost benefit analysis, and introduce stakeholders to suppliers (MLE Report_Period 4, pg. 11). The MLE report suggests inorganic fertilizer use is low among farmers because of "myths[,]... lack of adequate knowledge about fertilizers[,]... failure to distinguish between genuine and counterfeit fertilizer products[,].... and lack of knowledge about the economic benefits" of inorganic fertilizer (MLE Report Period 4, pg. 10). While these barriers may be true, insights from 60 Decibels research also suggest that financial constraints are a main hindrance for adopting fertilizer use.

SBPEA relies on a variety of research and scaling partnerships to carry out their work. Within SBPEA reporting, these partners are referred to as "scaling agents," who broadly fit in to the following "clusters": "government, NGOs, farmers' groups or associations, FM radios centers and private sector" (2017 Progress Narrative, pg. 7). In total, SBPEA partnered with approximately 70 scaling agents across both Uganda and Tanzania and implemented a scaling strategy developed in collaboration with the partners. Four areas underscored this strategy (2019 Progress Narrative, pg. 2):

- **Mobilization:** including radio shows and meetings with farmers and farmer groups
- **Active engagement:** including training of trainers, demonstration plots, and communication tools

- **Showcasing:** including farmer field days and radio shows
- **Integrated monitoring:** including farm-level checks, stakeholder meetings and "documentation of success stories" (2019 Progress Narrative, pg. 11)

In Uganda, radio campaigns included a number of questions that farmers answered via text message. This provided a way for project officials to gain data on farmer priorities over a large population; 20,525 Ugandans texted responses to radio poll questions. From this activity, SBPEA learned that though banana is an important crop for many farmers, access (or lack thereof) to capital hindered farmers' ability to "[adopt] key productivity improvement technologies" (2019 Final Narrative, pg. 13).

SBPEA also used other avenues to communicate with farmers across Uganda and Tanzania, including a SBPEA-produced film. The project also used digital media, including a project website (www.banagron.com), Facebook (https://www.facebook.com/groups/385107745368421/), and Twitter (https://twitter.com/AgronomyBanana). In collaboration with CABI, the development, testing and deployment of communication tools including "banana story chart[s], extension guide[s], dramas [and] radio programs." (2019 Progress Narrative, pg. 2). "[O]ver 2000 printed copies of the materials have ... been distributed" (2019 Progress Narrative, pg. 2).

Scaling agents were identified and partnered with differently across Uganda and Tanzania. In Uganda, SBPEA used the first reporting period to identify twenty-two scaling agents (2017 Progress Narrative, pg. 7). In the second reporting period, SBPEA visited 17 scaling agents to develop a 15-point scaling plan, sign memorandums of understanding, and map their social networks (2018 Project Narrative, pg. 12). The criteria for selecting scaling agents was based on the mapping of their social networks. In the third reporting period, 10 individuals from each Ugandan site came together for a training of trainers on the use of communication guides (story chat and extension guide). MLE found by end of the training that trainees reported a 78% score on knowledge obtained, but also identified a number of areas in which more training was needed: "how to plan for a training; the recommended spacing for bananas; proper disease management; and intercropping in banana plantations" (MLE Report Period 4, pg. 3).

Moreover, SBPEA has partnered with private sector stakeholders including fertilizer companies to promote fertilizer and the in-development fertilizer DST (2019 Progress Narrative, pg. 3).

Details regarding the use of scaling agents in Tanzania are limited. The 2018 Progress Narrative (pg. 13) provides less than a half of page of description of scaling agent activity, which mainly consists lists scaling agents by site. Additionally, a stakeholder analysis was not completed until end of the second project period, a year later than Uganda. In the third reporting period, 11 trainees from each Tanzanian project site gathered for a training of trainers on communication materials, however little information – especially when compared to the same event in Uganda – was provided either by the grantee or the M&E consultants (MLE Report_Period 4, pg. 4).

Lastly, 60 Decibels was brought in to conduct an evaluation of both scaling agents and farmers participating in SBPEA. They interviewed 52 scaling agents in Uganda.

There were many positives: a majority reported that their work has "very much improved" since working with SBPEA information; 96 percent reported improvements in their work, mainly in the area of "increased knowledge and skill thus better service delivery" (pg. 10); 88 percent

report reaching more farmers (77 percent more villages) because of materials and information received thru SBPEA (pg. 12). Across sites there were also some challenges. Top challenges included receiving information in English (that was not translated into local languages), slow delivery and/or limited access to materials to disseminate to farmers, and finally, a lack of access to credit, which inhibits farmers' ability to adopt best practices such as applying manure and fertilizer (60 Decibels – Scaling Agents, pg. 18).

Results Tracking Data

The grant aimed to integrate crop-soil management technologies and pest management practices in the development of DSTs by 2018 **(Results Framework 1.1)**. Most of the research in support of this intermediate target outcome was finalized in 2019, including literature reviews, assessment of synergies of ISFPM, and development of bio-economic models. SBPEA, however, pointed out that other model simulations were underway as well as model calibrations and analysis of data obtained from trials and farmer choice experiments, but most of these activities were projected to be completed in period four (2019–2020).

Given that some of the research was still ongoing by the time SBPEA submitted the 2019 RT, the target outcome to have new partners actively working with the project to adapt the DSTs to their own needs **(Results Framework 2.1)** was not met yet. The grant, however, reported that it already developed training and communication tools to inform scaling agents who are not partnered with SBPEA which would facilitate the use of DSTs. For example, they developed various farmer-friendly communication products and distributed brochures and other communication materials through which it met one of their output targets. The partnerships with CABI and close collaboration with farmer representatives and scaling agents to pre-test messages targeting various audiences, may have contributed to the grant's progress towards this target outcome so far.

In-Depth Interview Results

Interview respondents felt that having the grant be housed in a government research organization, NARO, allowed research technologies to be immediately distributed through ministry and government channels. The length of the grant affected the project in multiple ways. SBPEA focused on making systematic changes, but as was true for many of the foundation's portfolio grants, was run by researchers – so making market system changes, thinking about mainstreaming, scaling and sustainability were all new roles for a research organization, which may have contributed to the distribution of research taking longer than expected.

Project research was ongoing and as research technologies were developed they were disseminated to the scaling agents and local partners.

Interviewees described scaling via the thousands of farmers reached through extension workers, field days, demonstration trials, and local dramas and radio programs. Key partnerships with IITA and CABI allowed the project to leverage new skills and innovation, including developing and disseminating new communication materials to farmers and local scaling agents through a variety of mediums. Key local mobilization efforts, including close partnerships with farmers and scaling agents, allowed the grant to continuously involve local scaling agents and farmers in technology distribution.

Interview respondents also described a number of scaling challenges.

Managing expectations from stakeholders, particularly CBOs, small NGOs and scaling agents, was a challenge. Many stakeholders felt they should have received specific funding to participate in the project, and some decided not to participate because they were not receiving funding from the grantee. Although this was a scaling project, investment in the scaling aspect was minimal. Scaling agents, the government extension system, and NGOs had their own targets and priorities, and worked with a number of different crops, not just bananas, so there was no real incentive for them for them to prioritize this work over their other work. From the start of the project, SBPEA stipulated, through Memoranda of Understanding (MOUs) with scaling partners, that SBPEA's role was to provide scaling approaches and technical knowledge. The expectation was that partners would use these approaches and knowledge to provide services to farmers; as banana was a priority crop for scaling partners, it was assumed that scaling partners already had resources for this work.

> *"Because like, you know, government extension system, and their biggest challenge is that they have a big scope to cover in terms of geographical area, but also have limited financial resources to run this. And also, have other commodities that they are looking at, not just bananas. So for them to prioritize your enterprise banana would be quite challenging"*
>
> - Stakeholder respondent

Other interviewees felt that the project was unable to do any real scaling, even to neighboring communities, as the demand for research and the dissemination was only beginning to increase now, at the end of the project. While some districts and communities will have knowledge of the agronomic practices, how the information will continue to be distributed, packaged and sustained is unclear at this point. Interviewees recommended that the grant project should be funded for at least a 10 year project period.

Farmers often had limited access to inputs, such as fertilizer, manure and mulch; respondents felt an important aspect of this work was that technologies had to be in within the reach of the farmer. Many technologies recommended were labor intensive and/or the farmer needed additional money to use them, so these became barriers for farmers. So even when farmers had the knowledge of the best agronomic practices to produce the highest yields, they were not able to implement them due to cost and access.

> *"So, for instance, the fertilizer is a new innovation so people, especially small-scale farmers would begin imagining: so how - do I continue paying for fertilizer? They are taking it, some who have money, they sell to something them. But the smallholder farmers would want to use the inputs that are easily in their reach and affordable for those ones. If there are some water management basins, those ones are labor-intensive, and in most cases, labor is a challenge, because labor is also very expensive in those rural farming communities. So there are techniques or technologies that require a lot of cash, a lot of capital. Farmers don't usually rush for those ones. They would want to take on technologies that are friendly, that are affordable in their reach"*
>
> - SBPEA staff

These challenges were the main justification for step-wise intensification approach used by SBPEA, that farmers would first apply practices within their means, and then, in a step-wise manner, adopt other more capital and labor intensive practices as they generated more money

from the sales of the resulting produce. SBPEA believes that farmers should be able to adopt even capital-intensive practices as long as there is a financial benefit, and is trying to move subsistence farming to semi-commercial or commercial farming approaches.

On-Line Survey Results

Ninety percent of respondents to the on-line survey agreed or strongly agreed that SBPEA strengthened the capacity of extension agents to disseminate and promote new farmer technologies and tools. However, on-line respondents also indicated that extension agents still had room to grow their capacity to disseminate and promote new tools to farmers, including increasing training on the tools to be disseminated (89% of respondents), establishing better strategies to incentivize extension agents to promote tools (84% of respondents), and increasing opportunities for learning exchanges (74%) or involving private sector partners with more relevant business models (68%).

Summary and Main Lessons Learned for Scaling

Scaling was a major part of the work of SBPEA. SBPEA worked with a number of key partners who helped lead the scaling efforts and developed a clear scaling plan and strategy. The grantee also relied heavily on scaling agents in its scaling efforts. SBPEA and partners used traditional (plays, story charts, radio messages) and more innovative (social media, text message interactions with farmers) strategies to scale and disseminate their work, led by a partner that had extensive experience in similar scaling and communication channels and strategies.

The grantee highlighted this work in grantee documents and reported on this work in detail, detailing the numbers of farmers reached, the number of partners trained in capacity building for training. While not yet meeting outcomes related to farmers reached, the numbers nevertheless reflect the work conducted by the grantee to disseminate solutions despite delays in research which negatively impacted the time available for scaling and disseminating solutions.

While discussed briefly in the impacts chapter of this appendix, the increases in banana crop in the three regions of focus in Uganda may reflect a successful scaling strategy – where solutions were disseminated to large number of farmers who actually adopted these recommendations and practices.

Policy Development, Institutionalization, and Sustainability

SBPEA's approach to ensuring longer-term adoption of their research, agronomy solutions, and tools, including plans to institutionalize their work.

Document Review

As so much of the work of SBPEA was ongoing at the time of this evaluation, there was little information on policy development, institutionalization and sustainability in grantee documents.

Most of the project's self-described efforts towards sustainability (MLE Report Period 4, pg. 27-8) have already been mentioned, and include:

- Partnering with the Ugandan Ministry of Agriculture, Animal Industry and Fisheries
- Training of trainers with scaling agents
- The establishment of demonstration plots
- Development of DST for extension officer use

- "Involving the government extension staff within [and around] project sites" (MLE Report Period 4, pg. 27-8)
- Dissemination of banana hybrids
- Use of radio programming in disseminating agronomy solutions

However, of these, very few, if any, deal with institutionalizing project technologies, tools, or findings.

Results Tracking Data

As of 2019, targets for adaptation and validation of DSTs for use by scaling partners and their networks **(Results Framework 1.4)** were not met yet as the grantee was awaiting data from their research activities in order to develop the DST. Specifically, SBPEA reported that model simulations, farmer choice experiments, several yield gap trials, and co-learning workshops need to be finalized before it can move forward with the development and customization of the DST. SBPEA also refers to several challenges related to data collection and validation which, amongst others, included long procurement procedures for certain inputs, farmer's aversion to the application of mineral fertilizer, and data collection from trials.

In-Depth Interview Results

SBPEA had several approaches to sustainability and interview respondents discussed sustainability at multiple levels – the farmer level, research level and the market systems or value chain level.

Interview respondents thought that providing farmers, scaling agents, and extension agents with knowledge and information on best practices related to pest, soils, and nutrient management would incentivize adoption of these farming practices. While respondents were optimistic about continued use and adoption of these technologies, there was little discussion about how knowledge transfer, grassroots structures, and partnerships would be facilitated and sustained beyond the life of the project.

As the project progressed, SBPEA began to see a need to address market constraints using a value chain approach in order to support sustainability. With rapid increases in banana production attributed to farmers' uptake of the project's technologies, SBPEA realized that "the market is a key driver to production." Witnessing market prices for bananas drop, farmers were discouraged from using the technologies promoted by the project and interview respondents described that low prices for bananas would drive sustainability.

> *"Because of deployment of different practices productivity is going up, but less banana exported, not a lot of east Africa banana exported, mostly exported the apple banana. A lot of market outside therefore, many times, when farmers get skills that they deploy like this, they get the outputs and no benefits, they go back to their original way of doing things because they don't see the value"*
>
> - Stakeholder Respondent

Once these market challenges were realized, SBPEA intensified their collaboration with partners to encourage and support farmers groups and banana cooperatives, building on existing in-country (Uganda) models that exist for coffee growers, as ways to promote sustainability by pooling crops and better negotiating national and international prices for crops, and pooling

resources to access more affordable transportation to distant markets. These same partners and cooperatives were also exploring and encouraging the development and use of businesses for non-traditional uses of bananas – such as wine, etc.

Although SBPEA is developing a DST, stakeholders did not share sustainability plans for their DSTs. They did discuss, however, existing infrastructural challenges related to the reliability and coverage of in-country telecommunication networks, and literacy of target users and beneficiaries as challenges to using the tools, let alone the sustainability of these tools.

Summary and Main Lessons Learned for Policy Development, Institutionalization, and Sustainability

Because SBPEA was still in the development stage and conducting research, much of the focus of its work was not on sustainability, institutionalization and policy development. This situation was particularly true for its work on the digital DST, where the grant did not have much time to plan how the work on the DST would be sustained, since it was still in development. Many interview respondents also cited the limited time they had to work on grant activities beyond the grant period, given the single five year phase of funding.

SBPEA had an advantage over other grantees in the portfolio in that the lead for the grant project was NARO – the government agricultural research institute. Any of the research conducted and solutions developed, were automatically institutionalized into the work of NARO.

SBPEA relied on a number of its scaling partners and agents for its scaling and dissemination activities and planned to rely on these partners to continue to sustain the work of the grant project beyond the funding period. How these partnerships would be sustained and the availability of any funding needed to help sustain this work was unclear.

Impacts

SBPEA developed agronomy solutions uptake by farmers, increased productivity by farmers, and worked to strengthen supply chains.

Document Review

Overall, SBPEA recorded yield gains at most demonstration plots: “The upper limit of banana productivity increased from 40t/ha/yr to over 60t/ha/yr in Birere, Rwimi and Rombo; but only to 40t/ha/yr for Nakaseke and Izimbya. Between November 2017 and February 2019, modest yield increases of 2.5 -7.7t/ha/yr were recorded across the five sites of Uganda and Tanzania, with an estimated created value of US$ 3.04million.”

SBPEA reported a number of challenges related to demonstration plots, including farmer dislike of inorganic fertilizer (and thus reticence to adopt) and attrition of farmers participating in demonstration plots (2019 Progress Report, pg. 7; MLE Report_Period 4, pg. 13-15).

During the third project period, Bioversity International – the partner in charge of monitoring and evaluation – conducted spot checks of over 700 farmers in Uganda and Tanzania to measure productivity and management. While the third report from this period provides a dearth of data on what practices farmers were and were not using, the report does always not aggregate for whether farmers adopted new practices due to SBPEA exposure (MLE Report_Period 3, pg. 6-10). This lack of detail makes it difficult to assess if and how SBPEA is shaping farmer practice. However, in some cases the MLE Report *did* aggregate. For instance, in Tanzania the evaluation team found that “91% of the farmers sampled in Izimbya and 86% of those in Butulage farmers

are implementing the banana management technologies learnt from demo hosts and plots" (MLE Report_Period 3, pg. 9).

The grant documents state that the number smallholder farmers reached and value added may be underestimated given that these numbers do not include data from scaling agents because the project does not have a robust monitoring system in place to track progress made by scaling partners (SBPEA Progress Narrative, 2019).

Results Tracking Data

M&E data for SBPEA was limited, as the project was not completed at the time of the evaluation and still had a considerable number of activities to complete. The M&E data does not show notable discrepancies between targets and actual numbers, because there was limited information on whether or not the project had reached its final numbers.

The RT shows that SBPEA met half of its targets and half of its targets were not met. Given that the final monitoring data is not available, the results shown here are merely indicative of progress made thus far by the grantee.

SBPEA reports that 13,907 smallholder farmers were reached and generated an added value of USD 3.05 million (**Results Framework 1**). As mentioned in earlier, several interview respondents stated that the grant project's proposed practices and technologies led to demonstrable productivity gains and a higher than expected rate of adoption. This may indicate that SBPEA is progressing towards its target outcome of reaching 25,000 smallholders farmers and generating an added value of USD 11.5 million (Table B9).

Table B9. Results framework for SBPEA

	Target met	Target not met	Total targets
1. By 2020, 25,000 smallholders benefit from >USD 11.5M in higher banana yields	**9**	**12**	**21**
1.1 By 2018, soil and pest management technologies/practices integrated in DSTs	3	4	
1.2 By 2018, geospatial information integrated in DSTs	3		
1.3 By 2020, information on Xanthomonas recovery mechanisms used to refine the SDSR	2	1	
1.4 By 2019, DSTs are adapted and validated for use by scaling partners	1	7	
2. By 2020, at least new 6 partners use tools in their dissemination strategies	**1**	**2**	**3**
2.1 By 2020, new partners adapt DSTs to their own needs	1	2	
3. By 2020, innovative agronomy approaches integrated into NARS	**5**	**1**	**6**
3.1 By 2020, at least 5 NARS scientists effectively conduct agronomy research	5	1	
Total	**15** (50%)	**15** (50%)	**30**

In-Depth Interview Results

The achievements SBPEA were multi-fold, and occurred within a short implementation time. Most interviewees discussed the main achievements of the grant as being increases in banana yields and production from the start of 10 tons per hectare or less to 18 or 19 tons per hectare in the three pilot sites within Uganda.

> *I would likely say perhaps on an increase in banana production, though…that is still in its initial stages because then interventions were set out just about two years ago. So it*

will take time, But looking at the forecast and how things are going, it already shows you that we are going to have a boom of bananas on the market and that can already been seen even right now. And that would be to me a very great impact on the agronomy sector.

- Interview respondent

Interviewees described the thousands of farmers reached through extension workers, field days, demonstration trials, and local dramas and radio programs as being a large achievement or impact. Stakeholders cited building viable partnerships and relationships as key achievements. However, many of these activities that respondents described as achievements could also be attributed as factors that led to the achievements of increased banana production and yield.

Many respondents were unable to discuss the impact of the grant on the agronomy sector at the country level for Uganda, citing the short period of time that the grant was implemented and felt that it was too early to describe impact at the country level.

At this point in time, that is challenging to answer….a one size fits all for agronomy is being questioned. Context specificity is being readily embraced, more embraced than before this grant. That context specificity is something that is new and brought on by this grant. It's very important for enhancing optics because in many cases when we bring recommendations which don't fit the farmers' needs, [the farmer] puts them aside and that's it.

- Interview respondent

Other respondents described their thoughts on the more localized (in the three regions where the grant worked) impacts of the grant on the agronomy sector. For localized impacts, respondents discussed increases in banana productivity and improved knowledge of agronomic practices related to banana production as broader, key impacts on the agronomy sector, improvements in farmer and extension service learning related to agronomic practices, and improvements in marketing of banana systems (including the development of banana cooperatives and unions).

They also described some key learnings that they felt would change the agronomy sector in the future, including 1) "context specificity" – where the grant developed a number of new technologies that could be changed and adapted to the needs of each farmer; and 2) a newly developed understanding of the idea that while banana research was important, incorporating agronomic practices related to soil, nutrient and water management was a new way of approaching work with bananas and would be incorporated in this type of work moving forward.

Of course, it has built a lot of skills within especially the young, upcoming agronomists who are fresh from university, because now, for us in the private sector, those are the kind of people we normally look out for. So, eventually, when we see how the person is performing, we now take them on a permanent basis, because we know we have a skilled and resourceful person who has been trained to handle a project and who is now able to execute our business.

- SBPEA stakeholder

Two respondents discussed impacts as being improved food security for farmers and improvement of employment for individual households.

The grant project did fall short in terms of numbers of farmers it planned to originally reach and the increases in banana production per hectare (goal was to move from 10 to 25 ton/ha/yr but only reached 18-19 ton/ha/yr, however many of the farmers were not even initially producing at the 10 tons per hectare and the grantee did not realize this until the initial meetings with groups of farmers).

As discussed in earlier sections in this appendix, with increases in banana production, banana prices decreased, which may have discouraged farmers from continuing to implement technologies and thus may have limited project impacts. Other respondents discussed challenges with maintaining the scaling work after the end of the project, which could have a negative influence on longer term impacts.

Summary and Main Lessons Learned for SBPEA Impacts

SBPEA appeared to see increases in banana productivity in the regions where the project worked and reached over 13,000 farmers with its technologies, through a variety of communication channels which were a key focus of the project's scaling efforts. Increases in banana productivity indicate that farmers may have adopted these technologies after being exposed to them. Delays in finishing research and disseminating solutions limited the amount of time that solutions were available to farmers, therefore limiting the implementation of solutions. The work to create market systems for bananas may continue to help positive impacts, as it supports continued use of project technologies. However, overall the work of SBPEA is, at the time of this assessment, not fully complete. Additional impacts may be seen by the end of the project.

B4:TAMASA Summary

This appendix describes the Taking Maize Agronomy to Scale in Africa (TAMASA) grant project, summarizes the data collected and analyzed by the evaluation team on the TAMASA grant project, and provides lessons learned based on its implementation. The chapter starts with a brief description of the grant project followed by sections reflecting different parts of the Agronomy Grants Framework. For each of these sections, we present the data from up to four different sources (document review, review of the results trackers, in-depth interviews with grantees and stakeholders, and the online survey with grantee stakeholders; not all data sources are available for all parts of the framework). Each section concludes with a sub-section on lessons learned. The introduction to the appendices provides definitions and content for each section of this chapter. This review was conducted from February through April of 2019, so only reflect documents available and project activities conducted through that time period.

List of Acronyms

ADP	Agricultural Development Programme (Nigeria, extension)
AfSIS	African Soil Information Service
AGRA	Alliance for a Green Revolution in Africa
APS	Agronomic Panel Survey
BUK	Bayero University Kano (Nigeria)
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
DAO	District Agricultural Officers (Tanzania)
DSTs	Decision Support Tools
EIAR	Ethiopian Institute of Agricultural Research
EthioSIS	Ethiopian Soil Information System
FTF	Feed the Future
IAR	Institute for Agricultural Research (Nigeria)
ICT	Information and Communication Technology
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IPNI	International Plant Nutrition Institute
MAL	Ministry of Agriculture and Livestock (Ethiopia)
MoANR	Ministry of Agriculture and Natural Resources (Ethiopia)
MSA	Maize Seed Area (app)
MVS	Maize Variety Selector (app)
NAERLS	National Agricultural Extension and Research Liaison Services

NE	Nutrient Expert (decision tool)
NOT	Nutrient omission trial
OCP	Fertilizer company
R4D	Research for Development
SAA	Sasakawa Africa Association
SARI	Selian Agricultural Research Institute (Tanzania)
UAV	Unmanned aerial vehicle (drone)

Narrative Description of TAMASA's Activities

The Taking Maize Agronomy to Scale in Africa (TAMASA; 2015-2019) project, overseen by CIMMYT, sought to address the "attainable" yield gaps (the gap between actual and potential yields) in maize production in Ethiopia, Nigeria, and Tanzania. TAMASA's objectives were aimed to address four types of gaps: data, knowledge, adoption, and capacity/institutionalization.

TAMASA's main activities to close these gaps included:

1. **Generating geospatial data and nutrient omission trials (NOTs):** TAMASA's core work revolved around the cultivation of geospatial data, especially focused on soil profiles (including soil nutrients and soil moisture content) and the cultivation and publication of datasets. The goal of TAMASA's geospatial data collection and communication was to "better understand and predict the spatial and temporal variability of crop area, yield, management decisions and production outcomes" (Progress Narrative, January 2019, p. 2). One of TAMASA's main sources of data, the Agronomic Survey Panels (APS), was an annual household survey that measured "agronomic, yield and soil components ... at the time of harvest." To gather data on soil nutrient levels, in addition to the APS, TAMASA conducted nutrient omission trials (NOT)[22] across Ethiopia, Nigeria and Tanzania. Researchers also sought to find maximum efficiency in plant density for each country.
2. **Developing decision support tools (DSTs):** The development of ICT-based apps and DSTs was geared towards improving yields or farmers, service providers, and extension agents. TAMASA planned to create three DSTs including the Nutrient Expert tool (to provide site-specific fertilizer recommendations), the Maize Seed Area app (for plant population density), and the Maize Variety Selector (to provide site-specific seed recommendations).
3. **Strengthening country-level research capacity:** Complemented by the two activities above, in order to increase the national agricultural research capacity, TAMASA planned to sponsor researchers and data collection efforts. TAMASA originally planned to

[22] According to the International Rice Research Institute, a NOT is "The omission plot technique is used to estimate fertilizer requirements. In an omission plot, adequate amounts of all nutrients are applied except for the nutrient of interest (the omitted nutrient). The yield in such an omission plot is related to the indigenous soil supplying capacity of the omitted nutrient." http://www.knowledgebank.irri.org/training/fact-sheets/nutrient-management/nutrient-omission-plots

support 9 PhD and five MSc students, but with support from Bayero University Kano (BUK) in Nigeria was able to add three more, for a total of 12 PhD students supported.

Needs Assessment

How TAMASA identified agronomy research needs, the target users of the research, and how they prioritized the agronomy research needs.

Document Review

TAMASA's documentation identified broad and overlapping needs of target users across the maize value chain, including input suppliers, government and private research and extension services, agro-dealers, post-graduates, and smallholder farmers. The main process for prioritization of grant priority activities was via a stakeholder meeting conducted by TAMASA in Ethiopia in 2015.

TAMASA identified six areas that hinder maximum maize yields, including: "(i) inappropriate [government subsidies and government policy support]; (ii) poorly developed markets; (iii) lack of access to farm inputs – fertilizers & seeds; (iv) lack of access to farm credit (v) unfavorable weather conditions; and (vi) crop management practices" (CIMMYT Proposal, July 2014, p. 2). TAMASA suggested that the above constraints are largely related to the lack of data available to farmers, service providers, and agro-dealers.

TAMASA also suggested that making robust geospatial (i.e., location and farm soil profiles) and soil data (i.e., seed/fertilizer type and use) more accessible would inform advice given by extension agents, and allow private industry actors and farmers to tailor their products and inputs. Relatedly, TAMASA documented a perceived need for location-specific fertilizer recommendations.

In-Depth Interview Results

In-depth interviewees had some difficulty naming specific, or recalling the sequence of, efforts to assess the needs to prioritize for the project. The priorities had two main origins: pre-determined, from early in the life of the grant project; and an interactive approach with project partners.

Although some interviewees had difficulty recalling the sequence of prioritization, interviewees recalled meetings at the project and national level to discuss and develop a research agenda with different combinations of participants such as grantees, researchers, Foundation representatives, and other partners and stakeholders such as International Plant Nutrition Institute (IPNI) and International Maize and Wheat Improvement Center (CIMMYT).

TAMASA interviewees believed that the project's priorities were identified as early as the grant project application/proposal stage and might have been influenced by the Gates Foundation's existing priorities. The project proposals were considered a needs "roadmap," and the early meetings served as "navigation" to determine activities.

Given the rough "roadmap" approach, a few interviewees indicated that as the project progressed there was flexibility within the grant project to adjust the activities. For example, the DST team was able to adapt the development of the tools based on target user testing and buy-in. At the beginning of the project, the team assumed farmers would be the main target users of the tool. However, as time went on they realized that intermediary bodies such as service providers and extension systems were the more accessible target users. One respondent noted that the grantee

flexibility was helpful, given that determining the needs up front can be a challenge and that they did not find much traction locally – "the marching orders were difficult … come up with decision support tools that meet needs in a country context where it was difficult for our stakeholders to articulate what [their] needs actually were before [we said or showed] something." Another respondent retrospectively realized that the DST team did not put themselves in the role of the target users early enough.

On-Line Survey Results

Seventy-six percent of the TAMASA online survey respondents (13 of 17) reported that TAMASA prioritized their research based on the agronomic constraints limiting productivity. The next two highest factors that the TAMASA respondents felt were important to the prioritization of the project's research were the expertise of the research team (65%, or 11 out of 17) and the needs of beneficiaries (59%, or 10 out of 17).

The majority of the online respondents (10 out of 17, or 59%) felt that TAMASA had a good understanding of how to assess the demand for agronomic research; four respondents (or 24%) that felt TAMASA had an average understanding. This indicates that respondents had an overall positive view of the process, despite struggling to describe the activities in the in-depth interviews.

Most online survey respondents (15 of 17, or 88%) selected government sector agronomists/scientists as the main target users of TAMASA's research A majority of respondents (13 of 17, or 76%) reported the importance of smallholder farmers, agricultural extension agents, and academic agronomists/scientists/researchers. The blend of these target users across different levels of the agronomy sector show that the activities, specifically the DSTs, can be integrated at many levels.

Main Lessons Learned on Needs Assessments and Demand for Research

TAMASA assessed the needs for research up front in their application, proposal and planning phase of the grant project. Online survey results and the in-depth interview discussions also stressed the up-front decisions the project made, which were based on prior analysis of the maize agronomy landscape. Over time, TAMASA evolved and adapted their research and agronomy solutions to better meet the needs of stakeholders and target users, which was part of the learning process in developing DSTs. As the TAMASA project progressed, and stakeholders were able to see the delivery of the agronomy solutions, stakeholders were better equipped to explain what their needs were, which helped improve the project's understanding of what was needed to develop a DST.

Development

TAMASA's efforts to improve the capacity of local stakeholders to undertake research and development, research undertaken, and tailored agronomy solutions developed.

Document Review

TAMASA was a research-oriented project, with project officials and/or collaborating partner organizations undertaking at least a dozen research projects. Comparative and country-specific research aligned with TAMASA's objective to bridge data and knowledge gaps. Additionally, TAMASA aimed to close capacity and institutional gaps by supporting African graduate

students: 12 PhD students and five MSc students.[23] TAMASA-funded work and researchers produced over 30 datasets available via Dataverse, four research papers, and 10 more papers that are in development (over 30 more are proposed).

A main pillar of the grantee's agronomy research was data collection activities, specifically geographical and soil data. TAMASA orchestrated the annual household survey, the Agronomic Survey Panels (APS). Each panel consisted of approximately 750 households, and was carried out three times in Ethiopia and Nigeria, and twice in Tanzania. Through the APS, researchers sought to find the maximum efficiency in plant density for a country and compare it to the regional recommendation. In Ethiopia, APS research found the "optimum plant density is about 65,000 plants/ha," while in Nigeria, research found efficient density depended on seed variety (early, medium, long duration) and soil nitrogen levels. While the APS can answer many research questions, TAMASA initially focused on plant density as a potentially scalable way to close yield gaps and initiated the MSA on the basis of this work.

Another key focus of TAMASA was the development and use of geospatial datasets to predict new sites for maize production. The work was mostly in Nigeria, but was more complex than anticipated, as the project teams have encountered "unexplained variability at field level" (Progress Narrative, January 2019, p. 9). Two TAMASA-supported PhD students used spatial meteorological data to develop soil-moisture prediction tools to be integrated into the TAMSAT-ALERT decision support framework. TAMASA envisioned the tool would be used in Ethiopia, though program documents include neither a copy nor detailed description of the framework. The grantee clarified that PhD student projects ended after grant project did, so the grantee was unable to include the final outputs from the student work in project documents.

Nutrient management, and subsequent context-specific fertilizer recommendations, were core components of TAMASA. To gather data on soil nutrient levels, TAMASA conducted NOTs across Ethiopia, Nigeria and Tanzania. One use of this data was to develop maps of predicted nitrogen-, phosphorus-, and potassium-use efficiency in Ethiopia, called "spatial nutrient predictions."

A large, important and strategic part of the research for TAMASA focused on spatial modeling of input and output prices through collecting fertilizer prices from 18 sub-Saharan African countries (including Ethiopia) from 2010 through 2018. The goal was to predict fertilizer prices at specific locations within a given country. This output uses APS and integrates several disciplines and data streams. As part of this work, TAMASA conducted an extensive ex ante analysis of fertilizer profitability, finding that increased and context-specific fertilizer use can increase profitability.

Finally, the review of TAMASA's documents highlighted a few additional country-specific research activities. In Ethiopia, there was research on factors contributing to decomposing maize and also the profitability of nitrogen and phosphorus fertilizers. In Nigeria, researchers experimented with the use of UAVs to gather data.

The data TAMASA collected through the activities described in the project documents and summarized above was funneled into the development of the DSTs.

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[23] One PhD student had to drop out of their program and another is graduating later than expected due to a leave of absence.

- **Nutrition Expert** (NE) is an Android or computer-based program that provides site-specific fertilizer recommendations based on the input of specifics about soil and crops grown on a specific plot of land. It is a trademarked software, used globally and overseen by the International Plant Nutrition Institute (IPNI).
- **Maize Seed Area (MSA)** was developed in partnership with One Acre Fund and Precision Agriculture for Development (PAD) in Western Kenya, and is designed to help farmers more efficiently maximize plant population density. The initial pilot showed high interest from farmers, but indicated that advice might be needed for several years to see a change in practice. Field measurement, one aspect of the app, was highly valued among farmers but difficult for extension agents to carry out in practice.
- **Maize Variety Selector (MVS)** was designed to help farmers select the best seed variety for their circumstance. In 2019, TAMASA reported that their researchers found interest in information about varieties, but no "strong demand for predictions among target users such as farmers, agrovets or indeed seed-release bodies." TAMASA plans to promote MVS instead with seed producers and seed release organizations.

TAMASA was transparent in progress reports about the challenges with the development of the DSTs. These include expensive and time-consuming field trials, under-resourced partners who expressed an interest in using the NE tool but lacked the necessary resources, and skillsets that were outside the TAMASA team's capabilities.

Results Tracking Data

The first intermediate outcome (**Results Framework 1.1**) was met, given TAMASA's heavy emphasis on data collection and spatial analysis. TAMASA successfully implemented the APS to collect up to three rounds of farm-household panel data across the focus countries, and it collected over 8,000 crop-cuts and soil samples. TAMASA also published four papers following data collection, and they developed a knowledge base on spatial and temporal variation in agronomy. Building on the spatial-temporal data collection (**Results Framework 1.2**), TAMASA conducted spatial analysis, including soil fertility analysis, yield mapping, and price modeling, to guide its investments. The main challenge that inhibited the grant project from achieving some target outputs appeared to stem from difficulties related to the scale and logistics for spatial agronomy data collection, and perhaps data quality as in-field variability was very high.

OCP funded IITA, BUK and AfSIS to assess new maize fertilizer formulations in Nigeria, an activity that was linked to TAMASA, (**Results Framework 1.5**) by conducting NOTs, collecting soil samples, and updating digital soil maps. While the funded activity collected a large number of soil samples, the NOTs did not produce the data that could sufficiently explain spatial variation in yield responses.

TAMASA worked towards developing three DSTs: the nutrient management tool for site specific fertilizer recommendations - the Nutrient Expert (NE) tool (**Results Framework 1.3**), the variety options tool to provide site-specific maize seed recommendations - Maize Variety Selector (MVS) and the tool for guidance on plant variety's population density, the Maize Seed Area app (MSA) (**Results Framework 1.4**). The NE tool was developed and field-tested, and the grantee trained implementing partners on the use of the tool to support scaling efforts,

although it was not able to fully meet its targets. Demos of the other tools (MVS and MSA) were developed, but stopped short of testing and scaling and thus did not meet targets.

To increase the capacity in national agricultural research institutes (**Results Framework 1.7**), TAMASA involved and trained PhD and MSc students in agronomy research. Although the grant project involved fewer MSc students than anticipated, it involved more PhD students than initially targeted, with most of these students completing their PhD thesis.

In-Depth Interview Results

In-depth interview respondents from TAMASA spoke more generally about the objectives of the grant project's R&D and how TAMASA contributed to the changing field of agronomy research. While the document review emphasized that data collection activities complemented the development of the DSTs, some respondents put a heavier emphasis on the importance of TAMASA's work in improving the capacity for data collection. Interviewees felt that students who participated in the research would not have been able to collect data in this manner without grant project support.

One respondent recognized the heavy emphasis at the beginning on the development of DSTs, but reported that TAMASA's work in "modernizing" the ways of research in the region was highly important. The respondent felt that TAMASA was a thought leader through its work integrating spatial information and analysis in the growing "digital agronomy" field. The TAMASA grant project therefore created or designed "templates" or approaches for collecting and "organizing information and analyzing it and sharing it" for better agronomic research.

Online Survey Results

All of the online respondents agreed with the statement that TAMASA strengthened research systems capacity, with 55% "strongly agreeing" and the remaining 45% "agreeing" (6 and 5 of 11 respondents, respectively). These results mirror the testimonials from TAMASA staff from the in-depth interviews.

Summary and Main Lessons Learned on Development

The majority of the in-depth interviewees and online survey respondents felt that the TAMASA project strengthened research systems capacity. The document review, and opinions of the respondents from the interviews and survey, are in agreement about the importance of TAMASA's role in bringing spatial analysis and data into the agronomy research framework in the region. While the development of the DSTs was important, a lot of data collection work needed to be done first and refined to build the best tools possible. The publicly available data sets and transparent workflows from this project will allow reproducibility of TAMASA data collection.

Scaling

TAMASA's approach to scaling agronomy solutions, including dissemination of ideas and building the capacity of local stakeholders and institutions to scale or disseminate agronomy solutions.

Document Review

TAMASA's scaling activities started later than anticipated given the delays in finalizing the NE tool and other DSTs. TAMASA reported facing significant challenges in scaling because of the need to bring in additional digital service providers and partners.

The core scaling and extension activities reported in TAMASA's documents revolved around the NE tool, which was further developed than the other DSTs. TAMASA reported hosting field demonstrations of the NE tool in Tanzania with partners, including YARA, One Acre Fund, and Wageningen University. TAMASA reported that approximately 5,000 participants attended the field trials in Tanzania, of whom nearly 40% were women. In Tanzania, state extension officers received training on the NE tool, while extension officers employed by the Sasakawa Africa Association – not state officers – were trained in Nigeria. In Ethiopia, TAMASA conducted a training of trainers with the Crop Directorate and Soil Fertility Management Directorate, who later trained an additional 160 officials in NE use.

In Nigeria, OCP (a fertilizer company) has adopted NE in its work; OCP now uses the tool in Nigeria, Ghana, Togo, Burkina Faso, and Senegal. TAMASA reported in their progress reports that there were significant challenges to scaling the work in Nigeria: the extension agency expressed the desire to use the NE tool, but did not have the resources to do so. However, TAMASA identified future scaling partnerships in Nigeria, including Deutsche Gesellschaft für Internationale Zusammenarbeit ()/Green Innovation Centre for Agriculture and Food Security, PropCom, and the government extension agency. Moreover, in Nigeria work is under way with the state extension service (NAERLS) to adopt the automated Cropland Classification system, an ICT tool.

Scaling NE for new geographies may require more field-level testing, including NOT trials, which are time- consuming and expensive. NE will need continual fine-tuning to ensure its recommendations are realistic. For example, in Tanzania, the tool sometimes recommended fertilizer that wasn't available in markets, making the advice frustrating for farmers though useful for service providers. These challenges were part of the learning on DST implementation. To address these challenges, TAMASA also developed a more general fertilizer decision-making framework with ACAI and Wageningen University.

TAMASA conducted conduct two randomized controlled trials (RCTs), one in Ethiopia and one in Nigeria, to explore whether site-specific fertilizer recommendations led farmers to use fertilizer usage at recommended levels and if there was an associated positive impact on crop yields. Only the results of the Nigeria study were available at the time of this evaluation, and suggested that "providing advice does have a positive impact, and that advice on fertility management is also important." And "a key message from the RCTs….is that the 'how to' is as important as 'the what'. More research and testing of methods of effectively communicating advice at scale are justified and needed." (Progress Narrative 2019, pg 17)

There are questions about how to scale TAMASA's other apps, MVS and MSA. Project documents contain conflicting information about app scaling in Nigeria. The documents say that the Institute for Agricultural Research (IAR) in Nigeria expressed interest in "hosting MVS," but the team voiced reservations regarding whether they were the right home for it, as the IAR does not handle variety release, and Bayero University (BUK) was most likely to host the app. Moreover, the documents say MSA was never launched in Nigeria, but also says that Bayero University agreed to host *all* apps (MSA, MVS, and NE).

Conversations with the grantee clarified this information. BUK is a knowledge center and PhD students trained there have the expertise to host and support the DSTs. TAMASA would have liked to have had a business plan with BUK for this role, but did not. The business case proposed by TAMASA for MVS was that seed or variety release organizations were the logical hosts for

the DSTs, given that they collect the data needed to update any DST and could gain revenue from seed companies by including them in an app. TAMASA also tried to simplify the data collection and analytics for DSTs by including open-access code, to make it easier for national research institutes to adopt and scale.

In-Depth Interview Results

Only a few interviewees commented on TAMASA's scaling work, and they in general did not expect the project efforts to grow, since the DSTs were not scaled to a large number of target users. One respondent felt that the project generally recognized scaling as the ideal impact from the project, but that there was not enough time to achieve it. Overall, one interviewee felt that promotion and awareness of the project were weak, especially at higher levels, although better in Ethiopia and Nigeria. There appeared to be some disagreement among interview respondents in their understanding of the role of scaling in the work of the grant project. Researchers generally focused more on the legacy of TAMASA when the project ends, while other interviewees described scaling with farmers and developing better relationships with key stakeholders as goals of the scaling activities.

As with the document review results, the team seemed the most focused on the NE tool. Based on relationships with scaling partners, the interviewees were generally more hopeful about scaling in Ethiopia, and pessimistic about scaling in Tanzania. Respondents saw the involvement of OCP as beneficial because they had further reach and less self-interest as an African company serving Africa. However, there was also some hesitation from respondents on private businesses involvement, citing concerns that these would lose interest.

Respondents made a number of suggestions for promising pathways to scaling in the future. From the Ethiopia project, the tasks to prepare for scaling included making workflows, tools and methods replicable and discoverable, and using an open-source model. TAMASA's data collection successes formed a sort of free "handbook" for agronomy data collection which will promote best practices others may follow in the future. If future tools are scaled up appropriately, one respondent estimated that farmers could close over 50% of the crop yield gaps.

Suggested improvements for future tools included developing tools for each participating country, calibrated by personnel, skills and capacities; and documenting these factors. The interface of these factors should be considered to develop the simplest and most practical tool. Another respondent suggested that tools should be site-specific as well as stakeholder- and institution-specific. Others felt these issues (improvements and being tailored to sites, stakeholders and institutions) had already been addressed by the project, as the grantee ran user workshops in all three countries to generate these types of insights.

To be more effective, respondents suggested that projects should have a broader perspective, collaborate with more stakeholders doing similar work, and maximize use of other ongoing projects with similar objectives. In Ethiopia, it's essential to have a combination of good relationships with the government, understanding of its priorities, and buy-in for any grant project.

Suggestions that would have made scaling easier included, first, understanding how farmers operated, the logic for using fertilizer, and their knowledge barriers; and second, to gain wider scale acceptance, demonstrating to farmers and development agents through pre-scaling and rescaling, and ensuring target users had an understanding of the technique and how they could

account for their environments. This process would require "pushing" from multiple entities like the project and researchers to ensure development agents' uptake.

On-Line Survey Results

The respondents to the online survey mainly "agreed" or" strongly agreed" that TAMASA strengthened the capacity of extension agents to disseminate and promote new farmer technologies and tools. Out of the 11 respondents, seven agreed, or 64%, and three strongly agreed, or 27%. There was one respondent who selected "neither agree nor disagree" with the statement.

Despite largely agreeing that TAMASA strengthened the capacity of the extension agents, the respondents indicated that the extension agents could still benefit from some changes. Nine of the 11 respondents felt that trainings on the tools could be increased and better strategies to incentivize the extension agents could be developed and employed (82% of respondents). Most of the respondents also felt that both increasing the opportunities for learning exchanges and increasing the linkages to input distributors could also better strengthen the dissemination of the tools to farmers (both 7 of 11 respondents, or 73%). Finally, the respondents were more split on how effective it would be to involve more private sector partners (6 of the 11 respondents, or 55%).

Most of the online survey respondents named the limited reach of dissemination networks as the most prominent barrier in the adoption of the DSTs (10 of 17 respondents, or 59%). The lack of adequate cellular networks was also perceived as a barrier by respondents (7 of 17 respondents, or 41%), indicating that if disseminated and scaled the tools might have been inaccessible for the target users.

Summary and Main Lessons Learned for Scaling

TAMASA's efforts to scale their work came later in the grant project, given delays in producing the DSTs. As the interview and survey results show, TAMASA's respondents had mixed feelings about scaling achievements and a path forward. Respondents did provide productive and actionable suggestions and lessons learned for scaling; however, the scaling hinges on the completion and routine upkeep of the DSTs. Beyond the upkeep of the tools, the data inputs for the tools also need refreshing, which requires timely and expensive data collection and cleaning. All of these factors raise questions on the available resources, and which stakeholder(s) is/are responsible for continuing this work.

Policy Development, Institutionalization, and Sustainability

TAMASA's approach to ensuring longer-term adoption of their research, agronomy solutions, and tools, including plans to institutionalize their work through local stakeholders and institutions.

Document Review

Project documents made clear that ensuring the institutionalization and sustainability of TAMASA's work, specifically their DSTs, was challenging for several reasons. The lack of a feasible business model and strategy towards institutionalization made the sustainability of the NE tool difficult. The MVS and MSA tools did not reach a point where they could be disseminated or scaled, and their future is ambiguous.

In addition, TAMASA did not have a clear vision on how the NE tool could eventually be run profitably using a business model. TAMASA suggested that extension agents could charge

farmers and other stakeholders to receive advice from the NE tool, but it is unclear how much revenue this would create, and how attractive it would be to the consumers. Therefore, charging for the NE tool advice raises questions about barriers to adoption.

TAMASA did not document any engagement in policy development.

In-Depth Interview Results

Interviewees reported that DST products developed from TAMASA were not mainstreamed, and would not be sustained for a few reasons, these include a lack of institutional demand, time and resources to continue their use. Thus, several interviewees identified the importance of sustained funding and interest. One interviewee clarified that it was more than just the tools themselves – it included the approach and the way of working in many places.

From interviews, it appeared TAMASA did not have a clear strategy to institutionalize the NE tool or its MVS and MSA tools. One respondent remarked that a typical critique of projects that involve DSTs is that they sound like a good idea, but most don't define the theory of change and don't have buy-in or awareness of who may be ultimately committed to adopting such tools. In contrast, another interviewee pointed to activities that were moving the project in a good direction, such as interest from entities (e.g., World Bank, government, other countries, the Deutsche Gesellschaft für Internationale Zusammenarbeit/Green Innovation Centre for Agriculture and Food Security) and plans to submit manuscripts. Additional conversations with the grantee clarified that in Ethiopia the project worked to generate evidence needed by policy-makers to institutionalize DSTs, and that the project tried to link other soils work with the DSTs to get consensus on the best way to create demand and institutionalize the DST work.

A few respondents commented that the private sector could have been more involved in the strategy to scale and provide a route to commercialization. While in Ethiopia the private sector provides limited options, in Nigeria TAMASA partnered with a fertilizer company that is using the tool to provide advice to their farmer networks.

During the first years of the project, the grant project was primarily focused on the agronomy research and DST development, leading to delayed plans to mainstream the tools. Respondents felt the project primarily concentrated on developing the tool, and there was much less focus on who would be using it and how to embed it within institutions. As one respondent noted, "we realized as we went through that we hadn't done nearly enough around institutionalization or that side of things." While TAMASA has begun efforts to institutionalize their agronomy solutions, working with the Ministry of Agriculture and Livestock in Ethiopia, and BUK in Nigeria, some interview respondents were concerned about the extent to which the tool would continue to be used after the project ends, as the sense of ownership and commitment seemed limited. Similarly, other respondents were concerned that state institutions would have insufficient capacity and resources to maintain and update databases that serve as the platform for the tool and continue its dissemination.

Another respondent felt that the integration of the spatial analysis and the economic components into a decision-making framework has gained a lot of interest from researchers. The respondent expected to see "a lot more mileage from those methods."

Summary and Main Lessons Learned for Policy Development, Institutionalization, and Sustainability

TAMASA shifted their attention to institutionalization and sustainability too late in the grant project period to solidify and mainstream their activities. Respondents to the in-depth interviews were split between feeling optimistic and pessimistic about TAMASA's legacy, but mainly identified that sustained funding and resources (time and labor) are integral to the impact of DSTs. While the capacity for research and the new methods that TAMASA established in the regions were influential, there are many barriers to continuing the work TAMASA began.

Impacts

TAMASA's impact is derived more from their leadership in geographical and spatial research completed and their work to develop DSTs.

Document Review

TAMASA had the main objective of reducing four attainable yield gaps (data, knowledge, adoption, and capacity/institutionalization) in maize production. The grant project had a strong focus on data collection and spatial analysis. TAMASA originally focused on 1) generating geospatial data through household surveys and nutrient omission trials, 2) developing decision making tools, and 3) strengthening the country-level research capacity.

TAMASA had limited data on target outcomes and objectives realized, so it was difficult to assess whether or not the grantee had met target outcomes. Further, by the end of the project in 2019, priority appeared to have shifted to focus on specific types of experiments and sampling (e.g., household surveys and nutrient omission trials), the development of three types of decision-making apps, and the support for African graduate students.

Across activities, TAMASA had a number of outcomes, including 20 different tools created in the form of ODK mobile surveys, yield maps, or decision-support applications; 546 intermediaries trained, and 10,000 recommendations given to farmers across the three countries.

While the scaling of NE included an impressive number of partnerships, full adoption of the app's recommendations appear to be low, due mainly to lack of credit to purchase recommended seeds and fertilizer. According to a 60 Decibels study with 187 farmers: "less than a tenth of the farmers reported applying the recommendation in full. However, 74 percent of farmers reported understanding most of it and 51 percent reported applying most of it."

Approximately one-third of the 90 development agents surveyed by 60 Decibels on their use of NE reported difficulties using the NE tool: "they spoke of difficulty with using the application and issues with specific product features like GPS, speed, battery. Almost three quarters of our sample asked for additional training."

Results Tracker

TAMASA's Results framework included one primary target outcome (evidence on use of spatial data and methods) and eight intermediate target outcomes. TAMASA met 16% of the output targets, about 47% were not met, and about 34% of the targets were not clearly defined (Table B10). To test the impact of site-specific nutrient recommendations on farmer investment behaviors, the grant conducted an RCT on adoption and use of the NE tool, and submitted several peer-reviewed publications following these trials (**Results Framework 1.6**).

Table B10. Results framework for TAMASA

	Target exceeded	Target met	Target not met	Target/actual lacks clarity	Target/actual missing	Total targets
1. Evidence on use of spatial data and methods	**1**	**4**	**15**	**11**	**1**	**32**
1.1. Reduced knowledge gap on spatial and temporal variation in agrononomy	1	1	1	3		
1.2. Use of spatial ex-ante analysis to guide investments		3	3			
1.3. Nutrient management tool available			2	3		
1.4. Variety options tool available			4	1		
1.5. New maize fertilzer formulations evaluated			2			
1.6. Evidence on use of impact evaluation results by service providers			2			
1.7. Increased capacity in national institutes			1	1		
1.8. Project is effectively managed				3	1	
Total	**1** (3%)	**4** (13%)	**15** (47%)	**11** (34%)	**1** (3%)	**32**

In-Depth Interview Results

Those interviewed shared mixed reviews on what the main outcomes, impacts and achievements of the TAMASA grant project were. Several interviewees felt that TAMASA's impact was unknown or not expected, since tools did not scale to a large number of target users; however, a few interviewees cited TAMASA's impact on research. Several of the interviewees indicated that the lessons learned in terms of research products were invaluable for their team and for future research.

Despite challenges outlined previously, interviewees felt that students who participated in the research would not have been able to collect data in this manner without grant project support. Data generation was another project success, because of the maize production factors and the fact that data are made publicly available. One interviewee detailed that TAMASA's legacy "will be the articulation of spatially explicit ways of working with information … [which was] guiding investments – guiding policies, guiding recommendations ... [and] formalizing the lessons learned." The publicly available data sets and transparent workflows from this project will allow reproducibility of TAMASA data collection.

Another interviewee identified the NOTs, NE piloting, and training of the District Agricultural staff and enumerators as the most important TAMASA achievements.

Interaction with and learning from service providers – such as national agricultural research and extension services – was another achievement identified by a TAMASA interviewee. The interviewee reported that a major contribution was TAMASA's responsibility in shifting the thinking in partner institutions – from not pursuing the best solution for the whole country, but rather pursuing the best choice for smaller geographical areas, and thinking about the conditions that would make sense for particular farmers. This approach was somewhat reflected in the NE and extension partners, despite the fact that NE was not geospatially informed.

An interviewee felt that TAMASA had created a sort of "guidebook" or "framework" for agronomic modeling, sampling, and research, and indicated that it has captured a lot of interest:

"This spatial framework is kind of integrating some of the economic components that we know [are] important to how farmers make decisions into the same framework. And I think there's – that's captured a lot of interest certainly on the part of researchers. But I expect that we're going to get a lot more – see a lot more mileage kind of from those methods."

Summary and Main Lessons Learned for Impact

Even though there were mixed signals from respondents and interviewees on the impact of the TAMASA grant project, the project's contribution to research and the lessons learned from the project were a commonly reported theme. The results framework and tracking of TAMASA's outcomes were relatively weak, and made assessing the impact more difficult. However, the flexibility in the targets aligned with the needs assessment phase of the grant project, where the team made their activities adaptable. The priorities did shift over the life of the grant project, but TAMASA staff seem to perceive that the project contributed tools, developed thinking, and provided frameworks for future research and development.

B5: ACAI Summary

This appendix summarizes the data collected for the African Cassava Agronomy Initiative (ACAI) grant project and, based on the data collected, provides lessons learned from the ACAI grant project's implementation. The chapter starts with a brief description of the grant project. Sections reflecting different parts of the Agronomy Grants Framework follow (the chapters of the main report body also follow this structure). For each of these sections, we present the data from up to four different sources (document review, review of the results trackers, in-depth interviews with grantees and stakeholders, and the on-line survey with grantee stakeholders; not all data sources are available for all parts of the framework). Each section concludes with a sub-section on lessons learned. The introduction to the appendices provides definitions and content for each of the sections of this chapter.

List of Acronyms

CWMP	Cassava Weed Management Project
DSTs	Decision support tools
FB	Fertilizer blending
FR	Fertilizer recommendations
IC	Intercropping practices
IITA	International Institute of Tropical Agriculture
IVR	Interactive Voice Response
ODK	Open Data Kit
PP	Planting practices
QUEFTS	Quantitative Evaluation of Fertility of Tropical Soils
SP	Scheduled planting
TOC	Theory of Change
ToT	Training of Trainers

Narrative Description of ACAI's Activities

The African Cassava Agronomy Initiative (ACAI) is a $16.3 million project implemented by the International Institute of Tropical Agriculture (IITA) with the aim reduce the cassava yield gap by improving cassava root yield and quality, and cassava supply to the processing sector. The ACAI project, which started in September 2015 and is expected to end in December 2020, is formulated around six "use cases" developed in collaboration with stakeholders actively engaged in cassava value chain activities. These use cases are specific sets of information on improved cassava agronomic practices, and their translation into tools and applications that are affordable and accessible to extension agents providing recommendations to farmers and other beneficiaries. Working with a range of development partners in Nigeria and Tanzania, use cases are informed by cassava agronomy research, and used to develop and disseminate farmer decision-support tools and technologies.

Working towards reducing the cassava yield gap in Nigeria and Tanzania, ACAI is engaged in the following activities:

1) To provide the necessary insights into the impact of agronomic practices on cassava yield and root quality, it conducted strategic research on cassava growth dynamics, and nutrient and water requirements. Research includes field trials to better understand fertilizer response curves for cassava monocrop systems, development of cassava growth models, and assessing changes in starch content from agronomic interventions.
2) Development of a geospatial cassava agronomy information base which includes crop maps, soil constraint maps, and historical and near-real-time weather to guide site selection and extrapolate results from field trials.
3) Development of demand-driven and farmer-friendly decision support tools (DSTs) to provide site-specific recommendations for farmers growing cassava. DSTs are developed based on research and models of cassava growth dynamics and disseminated to farmers by partners working across the cassava value-chain.
4) Capacity development and institutionalization of new approaches for cassava agronomy development within the national agronomic research systems to strengthen engagement in transformative cassava agronomy.

Controlling cassava weeds and improving cassava weed management practices became another focus area of ACAI after it integrated the Cassava Weed Management Project (CWMP). CWMP, a $7.6 million project, started in September 2013 and is also led by the IITA, working in collaboration with Nigeria's National Agricultural Research and Extension Systems including two Nigerian universities. This project addresses the menace of weeds in cassava farming systems by assessing environmentally friendly and safe herbicides and exploring agronomic solutions including motorized mechanical options for weed control in cassava. Specifically, research to develop better weed management practices focused on:

1) Agronomic measures to control weeds, such as tillage, plant density, cassava variety, cropping system and fertilization.
2) Chemical measures to control weeds, i.e. herbicides.
3) Mechanical measures, primarily motorized weeders, and combinations of the best approaches in cassava fields.

Based on the findings of this research, the CWMP defined a "Six Steps to Cassava Weed Management" toolkit which has led to increases in cassava yields.

Needs Assessment

How ACAI identified agronomy research needs, the users of the research, and how they prioritized the agronomy research needs.

Document Review

Grant documentation shows that the grant took a demand-driven approach to the development and prioritization of use cases. After generating a list of active cassava value chain partners operating within the target countries, ACAI short-listed partners based on the level of active engagement in cassava value chain activities. Short-listed partners, as well as cassava scientists

from the national research systems, and key knowledge providers (e.g., the African Soil Information Service(), IPNI) were invited to stakeholder meetings. Prioritization of use cases and final selection of scaling partners were based on an assessment of factors such as their dissemination models, size of farmer networks, input supply chains, their footprint in the agro-ecological zones of interest, type of donor support, and number of extension agents in their networks. Through this participatory process, a total of 6 use cases were selected for implementation.

Grant documentation also explains the grantee's use of feedback loops to gather inputs from partners and other stakeholders. ACAI gathered feedback through, for example, field days and demonstration events. Feedback was used to further improve the DSTs and expand supporting materials for the use of the tools.

In-Depth Interview Results

Interview respondents confirmed ACAI's use of a demand-driven approach and the integration of feedback loops into their agronomy R&D processes. Partners were selected based on their ability to co-share the costs, their dissemination networks, and specificity of their needs. Respondents frequently referred to the demand-driven approach as an achievement because the co-development of the research agenda and the feedback loops created among partners a sense of ownership and commitment to adopt the technologies and disseminate the agronomy recommendations into their networks.

> *"Because whatever we try to do, we check with these partners, to be sure that we are not spending funds and coming back and saying this is not good, partners have rejected. […] What I see is that when you are able to go through this feedback loop, when it gets to the time for use, they run with it. Because they understand how that thing was developed; they have gone through the process with you."*
>
> - ACAI Staff member

Similarly, another respondent alluded to the role that demand-driven approaches can take in driving sustainability of outputs: "Being demand-driven and seeing partner's participation throughout the process up to now, it's really a process that […] would really help at the end in terms of sustainability, in terms of uptake."

While respondents emphasized the importance of involving partners in the design and implementation of agronomy R&D, one grantee respondent also noted that gathering feedback from partners at multiple stages of the R&D process can contribute to delays.

Asking about who the target users are, respondent's answers did not always align with the grantee documentation as farmers, private digital extension partners, and NARS scientists were also mentioned.

On-Line Survey Results

In the online survey, ACAI respondents selected and ranked the factors that most influenced the prioritization of research. Needs assessments of beneficiaries and the availability of partners with existing dissemination networks were ranked first and second. Agronomic constraints and the expertise of the research team were ranked third and fourth respectively, followed by adequate funding of the research, suggestions from the foundation, and government priorities.

Most respondents to the survey (84 percent) thought that the grant had a good understanding of how to assess demand for the agronomy research and only a few respondents (13 percent) perceived the grant to have an average understanding of how to assess demand.

More than 90 percent of respondents to the online survey perceived small holder farmers as the most important target user of the research, and just over 80 percent thought agricultural extension agents are the main target users. More than 50 percent of respondents also selected medium-scale farmers, government sector agronomists/scientists, and NARES as the main target user.

Main Lessons Learned on Needs Assessments and Demand for Research

Grantee staff considered the demand-driven approach and the integration of feedback loops to have contributed to its success in developing agronomy recommendations that meet the needs of target users. While gathering feedback from partners can cause delays to the implementation schedule, overall, grantee staff thought ACAI's approach to assessing the needs of partners and other stakeholders an achievement and an important approach to ensure adoption and sustainability of research outputs.

Development

ACAI's efforts to improve the capacity of researchers to undertake agronomy research, research undertaken, and tailored agronomy solutions developed.

Document Review

ACAIs agronomy R&D focused on agronomy research, development of DSTs, and the capacity building of NARS researchers.

The grantee's agronomy research comprised a large number of field and validation trials to (i) assess primary and secondary nutrient limitations in the target areas and varieties (ii) generate crop responses to nutrients and other agronomic interventions in cassava monocrop and intercropping systems, (iii) develop diagnostic tools to establish nutrient norms based on analyses of samples of appropriate plant parts, (iv) develop a cassava growth simulation model for mono-cropped and intercropped cassava (v) assess and apply nutrient response characteristics for cassava to develop the Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) framework to assess best nutrient management practices for profitable cassava production intensification, and (vi) assess the impact of agronomic interventions on the quality of cassava roots with a focus on dry matter and starch content. Following the integration of CWPM with ACAI, the grantee added a number of supplemental research activities including demonstration trials to measure the impact of weed control practices, understanding weed control and tillage interactions, and measuring the performance of alternative weed control techniques (ACAI Progress Narrative 2019, pg. 2).

To develop DSTs that provide site-specific recommendations, ACAI applied geospatial research to delineate geographical areas within which to apply recommendations. The grantee used geospatial sampling frames to assist in multi-locational trials that take into account variations in biophysical conditions with the target areas, incorporated soil constraint layers, yield gap maps, as well as historical and near-real time weather information.

Based on the agronomy research the grantee developed DSTs for each of the defined use cases and bundled these into one platform, which was branded AKILIMO. AKILIMO integrates the followed six DSTs:

- Site-specific fertilizer recommendations (FR) which provide nutrient management advice tailored to local soil conditions and crop calendars for sustainable cassava production intensification.
- Fertilizer blending (FB) which advises on appropriate fertilizer blends for cassava-producing geographical areas based on soil fertility conditions, cost of inputs, and potential demand.
- Best planting practices (PP) which guide farmers in choosing best-suited planting practices for cassava, with a focus on tillage operations and in close relation with improved weed control recommendations. (The Six Steps to Cassava Weed Management that was developed under the CWMP project, was integrated with the PP DST.)
- Intercropping practices (IC) which recommend intensification options (planting density and arrangement, varietal choice, relative planting time, and fertilizer application) in cassava-based intercropping systems.
- Scheduled planting (SP), which provides recommendations on scheduled planting and harvest dates to ensure a more continuous supply of fresh cassava roots to the processing industry.
- High starch content (HS), which recommends agronomic practices to optimize starch yields for cassava growers supplying the processing industry.

To build the capacity of NARS researchers, ACAI provided trainings in digital data collection and analysis to enable NARS scientists to apply and integrate principles of agronomy within their own initiatives and projects other than ACAI. Given the use of geospatial data in the development of DSTs, ACAI also provided training on geospatial analysis and the use of GIS data. Furthermore, ACAI supported a total of seven PhD projects and 13 MSc projects, integrated within the development of the use case tools (ACAI Progress Narrative 2019, pg. 2).

Results Tracking Data

ACAI met most of its output targets associated with the development of DSTs (see Table B11).[24] It met its intermediate target to conduct research on cassava growth and nutrient needs (**Results Tracker 1.1**) by reviewing the literature, document cassava response curves for different agro-ecologies, establishment of nutrient norms, QUEFTS modeling frameworks, cassava growth models, and determine the impact of agronomic interventions and weed control practices. It also met its targets to compile and integrate geospatial information to support the development of recommendation domains for each of the DSTs (**Results Tracker 1.2**). Output targets for the development of the DSTs (**Results Tracker 1.3**) were largely met. A few output targets were not met (yet) primarily because of delays with developing a fertilizer blend for cassava.

In-Depth Interview Results

Grantee and stakeholder interview respondents discussed achievements and challenges related to the agronomy research as well as the development of DSTs.

[24] ACAI's most recent monitoring data available to the Evaluation Team was from December 2019. As ACAI ends in December 2020, monitoring data of the last year is not included here.

Several respondents pointed to the project success in implementing a large number of field trials, demonstration trials and validation exercises conducted with the participation of partners and farmers. Stakeholder respondents reported that they participated in and led research activities in the field which helped them to further build their capacity to conduct agronomy research using large multi-locational field trials and develop their experience collecting data digitally. Respondents noted a few challenges related to field research. First, adoption of digital data collection across research partners was a challenge at the beginning of the project as agronomy research in Nigeria and Tanzania tend to use paper-based data collection methods. To ensure cost-effective data collection, ACAI had to train partners on the use of ODK before starting collection data. Second, limited funding and familiarity from partners to conduct agronomy research caused some delays in the implementation of field activities. Third, getting farmer's interest in participating in on-farm field trials was not always easy, especially where the project aimed to test fertilizers in cassava fields as many farmers have the idea that fertilizers are not necessary to grow cassava.

Respondents frequently mentioned that an important achievement of ACAI was the development of the DSTs for each of the use cases and the bundling of the separate DSTs into one platform, AKILIMO. Respondents saw AKILIMO as the result of ACAI's demand-driven and collaborative approach to agronomy R&D. Some also noted that the development of AKILIMO was partly a result of ACAI's ability to generate algorithms based on geospatial data, GIS layers and soil data of the African Soil Information Service ().

Capacity development to conduct agronomy R&D was also frequently mentioned as an achievement of ACAI although this came with some challenges. Respondents reported that ACAI invested in developing the capacity of NARS researchers and MSC and PhD students to conduct on-farm trials, use of statistics, digital data collection, and GIS. Some respondents were more critical of the capacity of NARS researchers to apply the skills and agronomy research approaches used under ACAI.

On-Line Survey Results

Online survey respondents either strongly agreed (63 percent) or agreed (37 percent) with the statement that ACAI strengthened NARS's capacity. Asked what the grantee can do to strengthen the capacity of NARS researchers, most respondents mentioned additional training and further improvements in the collaboration between key research institutes. Fewer respondents responded that research budgets and opportunities for learning exchanges can be increased, or that additional lab resources/instruments are necessary.

Summary and Main Lessons Learned on Development

ACAI's extensive agronomy research including multi-locations field trials and geospatial analysis led to the foundation of the development of DSTs. Respondents often reported that the demand-driven approach and participation of partners played a significant role in the completion of the agronomy research and development of the DSTs. Partner funding, adoption of digital data collection methods, and farmer participation were challenges mentioned by respondents. Especially the assumption that partners can and are willing to set-aside funding to support agronomy research appeared not always to be true and was considered an important lesson for future grants. And while ACAI implemented capacity building activities, some interview respondents were not certain about the extent to which trainings and workshops allowed NARS researchers to apply the skills independently.

Scaling

ACAI's approach to disseminating and scaling agronomy solutions, and building the capacity of local scaling partners and extension officers.

Document Review

Grant documentation shows that ACAI used different strategies to scale the DSTs (both paper-based and digital formats). Key to ACAI's scaling strategy is the involvement of scaling partners with extension networks in the design and implementation of the agronomy R&D. Scaling partners such as private sector organizations, NGOs, and farmer associations provided ACAI with extensive extension networks to implement field trials and validation exercises and disseminate DSTs.

Later in the project, the grantee began working with secondary partners to promote and scale DSTs outside of the ACAI project intervention areas. These secondary partners are input dealers, processors, marketers, and cassava cooperatives, of which some could address challenges within the cassava value chain such as access to finance, quality inputs, and market access. Through a rapid appraisal of 215 secondary partners in Nigeria and Tanzania, ACAI selected 18 secondary partners (ACAI Progress Narrative 2019, p.15). ACAI also worked with national extension systems to distribute the tools.

To facilitate the scaling of DSTs and improve access to the agronomy recommendations, ACAI sought partnerships with digital service providers. Digital service providers provide platforms for hosting and disseminating ACAI recommendation tools.

To support the delivery of DSTs into farmer's fields, ACAI trained extension agents in the use of the tools to equip them with the necessary materials, provide insights into how the tools function, how to apply the tools correctly, and how to integrate the use of the tools into their daily activities. Training of Trainer (ToT) workshops were implemented by IITA and NARS staff for the field coordinators of each primary partner organization who continued training their extension workers in "step-down" training workshops.

Results Tracking Data

ACAI set the target to onboard at least 10 partners or initiatives, in addition to their primary partners, who will use the tools within their dissemination strategies (**Results Tracker 2.1**). To work towards this target, ACAI engaged secondary partners to increase dissemination and adoption of DSTs. The grant exceeded its target to make at least 10 secondary partners per country aware of the DSTs as 42 partners in Nigeria and 27 partners in Tanzania have expressed interest to collaborate. ACAI monitoring data shows that 18 partners in Nigeria are using the DSTs but no partners in Tanzania were using the tools yet (see Table B11).

In-Depth Interview Results

Interview respondents echoed the approach to scaling as laid out in the grant documentation. Respondents, however, noted the tension between a grant which is mandated to conduct agronomy R&D and the down-stream activities related to scaling and marketing of the DSTs. With the agronomy research and development of tools taking most resources in the first few years of the grant, ACAI only began to focus more extensively on the scaling and dissemination of the tools in the last period of the grant. Thus time constraints put pressure on the grantee to scale the tools sufficiently and gain the momentum to sustain the DSTs. Another challenge was managing the expectation of extension agents, in particular agents in government extension

networks. Extension agents saw the integration of the DSTs in their extension activities as extra work and did not always see the added value of the tools.

As a result of ACAI's strong focus on agronomy R&D, respondents frequently reported that scaling of the DSTs was constrained by a lack of market-based approach. Several respondents said that uptake, and therefore scaling, was constrained by farmer's lack of access to inputs and credit. One respondent said: "…like bottlenecks to dissemination, an example, access to credit, access to input, all that were coming up and they were not part of the project, because this is agronomic project." Linking farmers with input and credit suppliers became a focus area of ACAI which began to select secondary partners who could facilitate access to these products and services. One respondent reflected on this approach: "At the moment also a lot of struggles are, now that we have the advice [DSTs], that farmers seem to have trouble to actually buy certain inputs, so we're trying to work with partners that work on credit facilitation."

On-Line Survey Results

Respondents either strongly agreed (60 percent) or agreed (40 percent) with the statement that ACAI strengthened the capacity of extension agents to disseminate and promote new farmer technologies and tools. However, online survey respondents also indicated that the capacity of extension agents could be further improved through more training on the tools they are disseminating (93 percent), better strategies to incentivize extension agents to continue the promotion of new tools (87 percent), by involving private sector partners with more relevant business models (87 percent), and increasing linkages to input distributors (80 percent).

Summary and Main Lessons Learned for Scaling

ACAI involved scaling partners extensively in the design and implementation of agronomy R&D with the aim to build their capacity and commitment to disseminate agronomy recommendations and scale the use of DSTs. Scaling partners included private sector organizations, NGOs, and farmer associations. In the last period of the grant, ACAI began to focus more intensively on scaling DSTs and thus began to expand their network of partners. Some of these partners could also facilitate access to inputs and credit, often necessary to adopt ACAI's agronomy recommendations. Reported challenges included time constraints as a result of the focus on agronomy R&D during the first years of the grant, incentivizing extension agents to adopt the DSTs in their extension services, and the lack of access to inputs and credit which was reported to potentially inhibit adoption of agronomy recommendations. Lessons learned, therefore, include the consideration of scaling strategies earlier in the project and the integration of market-based approaches in agronomy R&D.

Policy Development, Institutionalization, and Sustainability

ACAI's approach to ensuring longer-term adoption of their research and agronomy solutions, including plans to institutionalize their work through local stakeholders and institutions.

Document Review

ACAI envisaged achieving sustainability of agronomy R&D through institutionalization of agronomy research and tools with the NARS and by sustained delivery through the involvement of cassava value chain partners and digital service providers.

The institutionalization of new approaches for cassava agronomy research and the DSTs within the NARS systems relied on the early involvement and training of NARS researchers. The grantee involved NARS partners in the prioritization and implementation of agronomy research,

such as field trials, and built the capacity of NARS researchers to participate in and independently conduct transformative agronomic research. It also trained NARS researchers to apply and integrate the principles of agronomy within their own initiatives and projects other than ACAI (see section on development above for more information). The development of skills such as geospatial analysis and data base management also served to maintain the DSTs when the grant expires.

To sustain the dissemination of DSTs, the grantee built on the extension networks of their partners and it involved secondary partners in the cassava value chain partners interested in integrating the DSTs in their services. "Ultimately, these linkages will aid in ensuring the sustainability of the AKILIMO decision support service" (ACAI Progress Narrative 2019, pg.15). Furthermore, digital service providers are also envisioned to play a role in the sustained dissemination of the DSTs as they are not only improving access to the agronomy recommendations for farmers but they are also disseminating the DSTs using their service model.

The policy environment ACAI faced created both challenges and opportunities for success. In the Progress Narrative Report of 2019, ACAI noted that they faced challenges with the development of a fertilizer blend, noting that "…nutrient import restrictions by the Nigerian government…" delayed production of a blend. On the other hand, ACAI successfully built on the work of CWMP by advocating for the suspension of the importation of the herbicide paraquat due to safety concerns. After engaging a small team of consultants, they worked with the National Agency for Food and Drug Administration and Control (NAFDAC) and the Ministry of Agriculture on modalities to deregister paraquat while accepting alternative and safer herbicides (ACAI Progress Narrative 2019, pg. 16).

Results Tracking Data

ACAI's aimed to have NARS scientists integrate agronomy approaches in NARS-led initiatives by 2020 (**Results Tracker 3.1**). Most related output targets were met or exceeded through trainings and workshops for NARS scientists, and PhD and MSc students (see Table B11).

In-Depth Interview Results

Discussions about the sustainability of ACAI's agronomy R&D showed that ACAI aimed to both sustain the agronomy R&D and developed a strategy to sustain the delivery of agronomy recommendations into farmer's fields.

To continue agronomy R&D, including sustaining the DSTs, respondents referred to the role of public sector research institutes. Continued training and additional funding to continue the research and the maintenance of the tools were mentioned as pathways to sustainability for these institutes. For example, one staff respondent said that "developing a learning platform where people can download materials and videos and basically self-learn" is a way to continue capacity development after the project ends.

To continue the dissemination of DSTs, respondents noted the importance of scaling partners and digital service providers. Stakeholder respondents involved in the dissemination of agronomy recommendations, expressed their interest in continuing the use of DSTs, and staff of ACAI confirmed they were also involving secondary partners to further scale in other geographies and improve access to inputs and credit. Digital service providers were frequently mentioned as a strategy to scale with one respondent noting that "…these digital partners who have business

plans and strategies in place, who have commercial source of funding also by linking with some of the bigger input dealers or with banks."

Despite these strategies, a number of respondents also expressed concern about the sustainability of the agronomy R&D. Two ACAI staff noted that they are in the process of identifying and engaging NARS institutes in the institutionalization of the agronomy R&D but no formal partnership seem to have been established which would allow the phase-over of responsibilities of maintaining the DSTs. Some respondents also raised some concerns about the technical capacity to maintain the DST. Despite ACAI's efforts to train NARS researchers, there remains uncertainty about their skills to maintain the DST, and especially about the extent to which they will be able to update the DST when expanding into new areas.

Regarding the sustainability of the delivery of DSTs, respondents noted that ACAI is still piloting the approach of using digital service providers. Given that digital service providers are still looking for funding to maintain the maintenance costs, the viability of this approach remains to be seen.

Summary and Main Lessons Learned for Policy Development, Institutionalization, and Sustainability

Ensuring the sustainability of agronomy R&D and the delivery of agronomy recommendations to farmers led ACAI to focus on both the institutionalization of agronomy R&D in NARS institutes and by developing a network of scaling partners and digital service providers. With a focus on agronomy research in the first few years of the grant, ACAI only began undertaking measures towards sustainability in the final period of the grant. Interviews with ACAI staff showed that no partnership to institutionalize the agronomy R&D has been formalized and that digital service providers, who play a critical role in continued delivery of agronomy recommendations, are still looking for funding to cover the costs of delivery.

In order to ensure the sustainability of agronomy R&D and its delivery into farmer's fields, future grants may need to consider earlier in the investment period and in more detail what the potential sustainability pathways could be. The consideration of institutionalization options and the potential business model that could be used for sustained delivery may help to ensure sustainability.

Impacts

ACAI developed agronomy solutions that were taken up by partners, increased productivity by farmers, and worked to strengthen supply chains.

Document Review

ACAI's grant proposal laid out a TOC with four impact goals: 1) increased productivity and diversity of cassava systems, 2) food security and nutritional status and income enhanced poverty reduction, 3) enhanced continuity of supply of cassava to markets and processors, and 4) sustainable use of natural resources and agro-inputs.

Increased productivity and diversity of cassava systems: The 2019 Progress Narrative referenced how agronomic practices and technologies improved yields. Referencing yield data from field trials and validation exercises, ACAI, for example, demonstrated that fertilizer recommendations improved cassava yields by 7 t/ha in Nigeria and 4 t/h in Tanzania on average. Translating this to revenue, they observed that nearly 60 percent of participants in Nigeria saw a positive revenue increase, while this was over 40 percent in Tanzania. They note, however, than yield increased

were often lower than predicted. Recommended weed management practices from validation exercises also showed yield increases of 5–10 t/ha compared to the status quo. Similarly, intercropping recommendations showed that increasing maize density without supplying fertilizer rarely resulted in maize yield increases, while fertilizer application increased yields for 80 percent of participants, and intercropping with sweet potato increased yields in 68 percent of the fields.

Food security and nutritional status and income enhanced poverty reduction: Grant documentation did not explicitly reference the impact on food security but with proven increases in yields and integration of DSTs in partner dissemination networks, the grantee's body of research likely contributes to improved food security. Grant documentation also does not show how the grantee impacts the nutritional status. It reports, however, on factors that influence starch content following field trials.

Enhanced continuity of supply of cassava to markets and processors: ACAI connected and worked with a range of partners in the cassava supply chain to increase yields and improve the supply of cassava. Its scheduled planting use case, in particular, aimed to enhance the continuity of supply of cassava to the market. The extent to which the use case enhanced the supply of cassava was not clear. In the Progressive Narrative report, they state that yields obtained from a series of validation exercises did not produce data that could be used for the evaluation of the DST due to higher levels of random error.

Sustainable use of natural resources and agro-inputs: grant documentation did not reference the grantee's impact on sustainable use of natural resources and agro-inputs.

Results Tracker

The RT of ACAI included one impact target to have at least 120,000 farmers benefiting from an added value of USD 28M by 2020 (**Results Tracker 1**), through higher cassava yields, higher starch content, a more continuous supply of roots, and/or the use of appropriate cassava fertilizer, within the target areas in Nigeria and Tanzania (see Table B11). The RT shows that this target was not met (yet). ACAI's Progress Narrative (2019) stated that they reached 23,623 households as scaling activities began later than planned. ACAI stated, however, that it is confident that they will reach the outcome target since dissemination activities will be intensified with primary partners and the DSTs have been integrated into their dissemination activities.

Table B11. Results framework for ACAI

	Target exceeded	Target met	Target not met	Target/actual lacks clarity	Total targets
1. By 2020, at least 120,000 farmers benefit from added value of USD 28M	**8**	**9**	**7**	**3**	**27**
1.1 By 2017, research on cassava growth and nutrient needs integrated in DST development	1	5	3		
1.2 By 2017, geospatial information integrated DST development	1	3		1	
1.3 By 2018, cassava agronomy DSTs used by primary partners	6	1	4	2	
2. By 2020, at least 10 new partners use tools in their dissemination strategies	**1**		**1**	**2**	**4**
2.1 By 2019, new partners adapt DSTs to their own needs	1		1	2	
3. By 2020, NARS scientists integrate agronomy approaches in NARS-led initiatives	**1**	**4**		**2**	**7**
3.1 By 2019, at least 5 scientists per NARS led implementation of activities	1	4		2	
Total	**10** (26%)	**13** (34%)	**8** (21%)	**7** (18%)	**38**

In-Depth Interview Results

ACAI respondents identified a number of potential impacts of ACAI on the agronomy sector:

Firstly, several **r**espondents referred to the increased productivity and competitiveness of farmers who follow up the agronomy advice. Respondents reported considerable increases in productivity as a result of adoption of agronomic practices or technologies recommended by ACAI while recognizing the productivity will vary depending on farmer characteristics. One respondent mentioned that those who apply the recommendations of the DST, see their productivity go up by 25 percent with few farmers seeing productivity increases below 25 percent.

With increases in farmer productivity comes the potential to increase competitiveness. Farmers who increased yield also increased their potential to become more competitive as they were able to sell larger quantities to the market which allowed them to sell at better prices and meet the demand of cassava processors.

Secondly, several respondents said that ACAI brought increased collaboration and coordination among partners in the cassava value chain and forged partnerships that did not exist before the project. One respondent gave the example of collaboration between private sector partners, such as a fertilizer company that now works together with a cassava processing plant. ACAI was also key to create collaborations between public sector partners, NGOs, and other private sector partners through its agronomy research.

Thirdly, respondents frequently pointed to ACAIs impact on thinking about approaches to agronomy research. Respondents frequently mentioned the demand-driven approach, multi-locational research to generate site-specific recommendations, and the application of digital technologies in conducting agronomy research. The strong engagement of partners in design and implementation of the research agenda was considered both innovative and effective which, as one respondent put it: “I think it brought a new way of thinking. Innovativeness in terms of, as number one, of course, engagement with the partners – letting the partners tell us what they want, not us creating what we think they want.”

Conducting multi-location research with partners to be able to generate site-specific recommendations was considered to be innovative as well. One respondent who was involved in the agronomy research reported that agronomy research traditionally did not have a great number of breakthroughs because it was assumed to be highly local and specific to a particular situation which makes it difficult to apply recommendations to other areas. However, “Now, the approach that ACAI has chosen has taken this argument out completely because it's multi-locational – don't do big experiments, but do many, in as many different places as possible to cover the variability in the conditions – soil conditions, rain conditions, whatever the conditions may be.”

The application of digital technologies was also considered to have impacted thinking about agronomy research. Not only did ACAI press the use of digital data collection tools, such as ODK, but also developed DSTs and involved digital scaling partners. Traditionally, agronomy research did not involve many digital technologies, but as one respondent puts it: “I think we have paved a way. […] So with this entry of DSTs that are digital with farmers being able to have an IVR with a code to punch and then to have a recommendation, I think that is something big in the agronomy for cassava.”

Summary and Main Lessons Learned for Impact

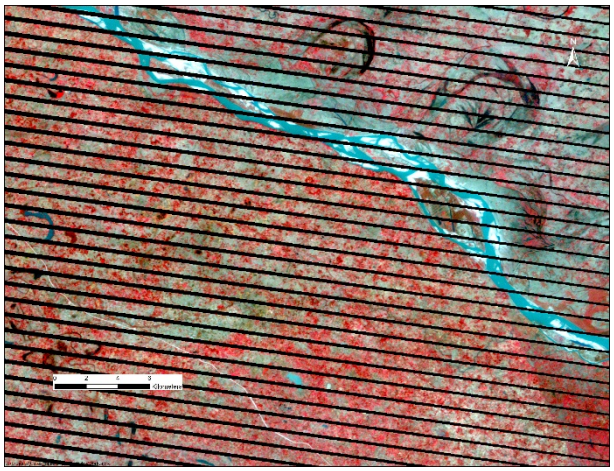
Grant documentation and in-depth interviews provide qualitative data on the potential impact ACAI has had on the cassava value chain or at the country level but the data does not allow us to quantify impact. Grant documentation does not specifically report on the impact of the grant, although the TOC details the final impact the grantee may have. Interviews with ACAI staff and stakeholder respondents show they perceived the grant to have positively impacted the productivity and competitiveness of farmers and that the grant brought increased collaboration and coordination among partners in the cassava value chain. ACAI's approach to agronomy research is also said to have impacted thinking about approaches to agronomy research with respondents referring to the demand-driven approach, multi-locational field trials, and the application of digital data collection methods.

Appendix C: Geospatial Analysis

Geospatial Analysis

We used satellite images to assess the adoption of early sown wheat across districts in Bihar and Uttar Pradesh. More specifically, we relied upon the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) satellite imagery to estimate the change in sowing date of wheat between the pre-program (2012-2013) and post-program (2019-2020) implementation during the *rabi* season. The Landsat satellites are Earth observation satellites, operated by NASA and the United States Geological Survey, that provide publicly available images of the Earth's surface. We originally planned on using a combination of Landsat 7 (ETM+) and Landsat 8 Operational Land Imager (OLI) imagery, as both platforms collect similar eight-band multispectral imagery globally, at 30-meter resolution,[25] and with a local revisit time of 16 days. As the Landsat 8 imagery was not available for the 2012 season,[26] the idea was to supplement Landsat 7 imagery with Landsat 8 to increase the number of cloud- and smoke-free images that could potentially be used in the analysis, as there is an eight-day offset in the revisit dates. However, during processing, two issues became apparent that limited our analysis to using imagery from Landsat 7 ETM+ only. The first issue involved gaps in the Landsat 7 ETM+ data, caused by a Scan Line Corrector (SLC) failure in 2003[27] (Figure C1). The second issue concerned slight differences in spectral bands between the satellites, which meant that we could not confidently determine whether changes in our classification were due to differences in ground condition and not differences between the sensors.

Figure C1. Landsat 7 ETM+ data gap issues caused by SLC failure in 2003 (false color infrared imagery, bands 4, 3, 2). Data gaps shown in black striping.



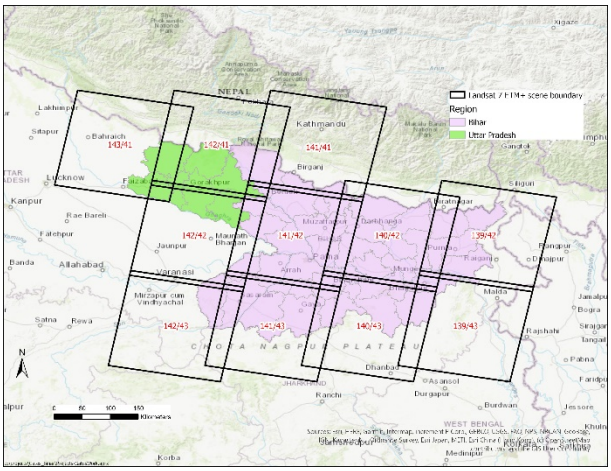
[25] The Enhanced Thematic Mapper Plus (ETM+) sensor contains eight spectral bands covering the visible (30m resolution), near-infrared (30m), mid-infrared (30m), thermal (60m), and panchromatic (15m) bands.

[26] Landsat 7 was launched on April 15, 1999, while Landsat 8 was launched on February 11, 2013.

[27] On May 31, 2003, the SLC failed the Landsat 7 satellite. Since June 2003, the sensor has acquired and delivered data with data gaps caused by the SLC failure. (https://www.usgs.gov/land-resources/nli/landsat/landsat-7?qt-science_support_page_related_con=0#qt-science_support_page_related_con)

Crop calendars provided by the Ministry of Agriculture suggested that the sowing date of wheat for Bihar was between mid-November and early December, and between early October and mid-January for Uttar Pradesh. As environmental conditions vary year to year, we acquired as many Landsat 7 satellite images ("scenes") as possible between October 1, 2012 and 2019 and March 1, 2012 and 2019 in order to discriminate the sowing date.[28] As noted above, Landsat 7 imagery is available every 16 days by individual tiled images ("scenes") denoted by Path and Row. Images were selected based on the date of the image, and percentage of cloud coverage. An image that had > 50% cloud was excluded from the data. Eleven scenes were needed to cover the spatial extent of the districts across Bihar and Uttar Pradesh (Figure C2) for each date. In total, we acquired and evaluated 231 images. While we did not expect cloud cover to be an issue in the *rabi* season, we found that 59 images had 50% or more cloud cover and were therefore unusable. An additional 29 images were either missing or not usable due to poor atmospheric conditions – presumably due to smoke cover. Therefore, 38% of the imagery, distributed across all regions and over the two time periods, was not useable in our analysis.

Figure C2. Landsat 7 scenes needed for analysis



Our proposed approach was to classify and quantify the area of two land cover types: wheat and non-wheat. In our initial analysis, we used a variety of remote sensing techniques to examine our ability to discriminate between land cover and crop types in the multispectral imagery. Using ground truth data from 2015 and 2017 provided by researchers in India (Balwinder), we evaluated a number of classification techniques, including traditional supervised classification, a machine learning-based supervised classification (Random Trees), and unsupervised classification. After assessing the results, we determined that we could not differentiate between crop types in a defensible manner – especially given the absence of ground truth data for the time periods needed to conduct an accuracy assessment. Additionally, the data gaps caused by the SLC sensor failure meant that we would not be able to quantify the area of crops grown.

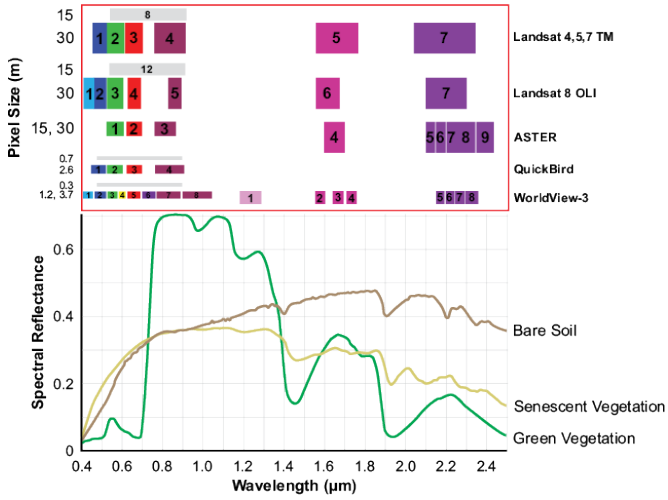
Given the limitations in data and ability to differentiate between crops, we therefore determined that our best course of action was: a) to classify the land cover into crop and non-crop areas, and b) to determine whether the sowing date (determined through green-up) had shifted between pre- and post-program years. Additionally, because of the variety of green-up dates across the region, we conducted our analysis independently for each scene, rather than combining scenes into a single image. This meant that we could not determine when the green-up occurred within the range dates.

We evaluated a number of vegetation indexes to help classify the imagery into crop and non-crop areas as well as determine the green-up date. Vegetation indexes are mathematical combinations or transformations of spectral bands that enhance the spectral properties of vegetation versus

[28] We downloaded imagery from two USGS government sites – earthexplorer (https://earthexplorer.usgs.gov) and landsatlook (https://landsatlook.usgs.gov).

non-vegetated areas. Additionally, as reflectance is associated with the amount of chlorophyll content in the leaves, it is not only possible to differentiate between vegetated and non-vegetated land cover, but also to assess how vigorous the vegetation growth is. Figure C3 shows the spectral profiles of soil, green vegetation, and senescent vegetation, and the relative location of each profile within the spectrum covered by Landsat bands. Vegetation indexes capitalize on the relative differences between reflectance values in the Near Infrared band (Landsat Band 4) and the Red band (Landsat Band 3) between these different land cover types.

Figure C3. Spectral profile of healthy and senescent vegetation and bare soil and associated multispectral bands by satellite platform (source: USDA Natural Resource Conservation Service – https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054255).



We evaluated several different vegetation indexes to classify crop/non-crop areas, including the Normalized Difference Vegetation Index (NDVI), the Soil Adjusted Vegetation Index (SAVI), the Enhanced Vegetation Index (EVI), and the Perpendicular Vegetation Index (PVI). There are pros and cons to each of these indexes, and they all performed well for certain areas and specific images, but had misclassifications across other images. To accurately classify vegetation using these indexes, we found that the thresholds used to differentiate land cover types would need to be tailored to each image independently, because of a combination of the sensitivity of the indexes and the spectral variability of the imagery across scenes (both space and time). However, while it would have been possible to adjust the thresholds for each image (rather than using a single threshold for all imagery), this would introduce additional uncertainty as to whether the change was due to the threshold adjustments or due to changes in the land cover – especially given the lack of ground truth data for each image. We ultimately determined that the Simple Ratio (SR), which is a basic ratio off the near infrared and red bands, was the most consistent index to use across the time periods and scenes for our purposes. While the index is relatively simple, it is less sensitive to minor differences in spectral characteristics caused by atmosphere and shading from topography, thereby allowing us to use a consistent set of thresholds across all the imagery. The SR index is high for vegetation and low for non-vegetated land cover, and also gives a relative indication of the amount of vegetative cover. The SR index is shown in equation 1:

$$SR = NIR/Red \quad \text{(equation 1)}$$

Where "NIR" is the near infrared band (Band 4) and "Red" is the red band (Band 3).

Classifying and Quantifying Land Cover Types

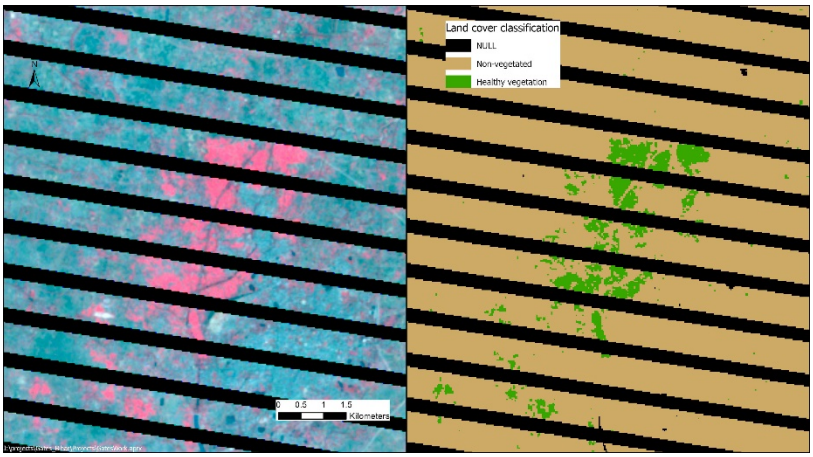
Before classifying the pixels of each image, we first corrected for additional atmospheric effects by running the Apparent Reflectance raster function available within ArcGIS Pro software (ESRI, 2020[29]). We then calculated the SR index to measure the relative health and quantity of vegetation within each pixel. We used ground truth data and imagery from 2015 and 2017 to determine the index thresholds needed to classify land cover into healthy vegetation, non-vegetated areas, and missing or bad data. The classification thresholds are shown in Table C1:

Table C1. SR index values and associated classification

SR value range	Classification
0 – 1	Null (bad data in imagery, etc.)
>1 – 2.7	Non-vegetated (e.g., urbanized, barren), vegetation with low vigor, or fallow
>2.7	Healthy vegetation

We then clipped the image to the district boundaries within each scene, and reclassified the pixels into their associated land cover type. Figure C4 shows an example of the classification effort – with false color infra-red raw image input on the left and the land cover classification on the right for a single Landsat scene. It should be noted that by using SR values greater than 2.7, we falsely identified as crop some areas of forest – especially in the northern scenes. However, as we ultimately used the *change* in total amount of area classified as vigorous vegetation, since forested areas do not change between dates (unless there is deforestation), any differences will be associated with the green-up of newly planted crops.

Figure C4. Example of classification. Left: Landsat 7 ETM+ raw imagery (false color-infrared, bands 4,3,2). Reds indicate level of vegetative vigor; blue/green and gray colors indicate non-vegetated areas; black areas are NULL data. Right: classified image based on Simple Ratio (SR) index. Imagery date: 12/6/2019.

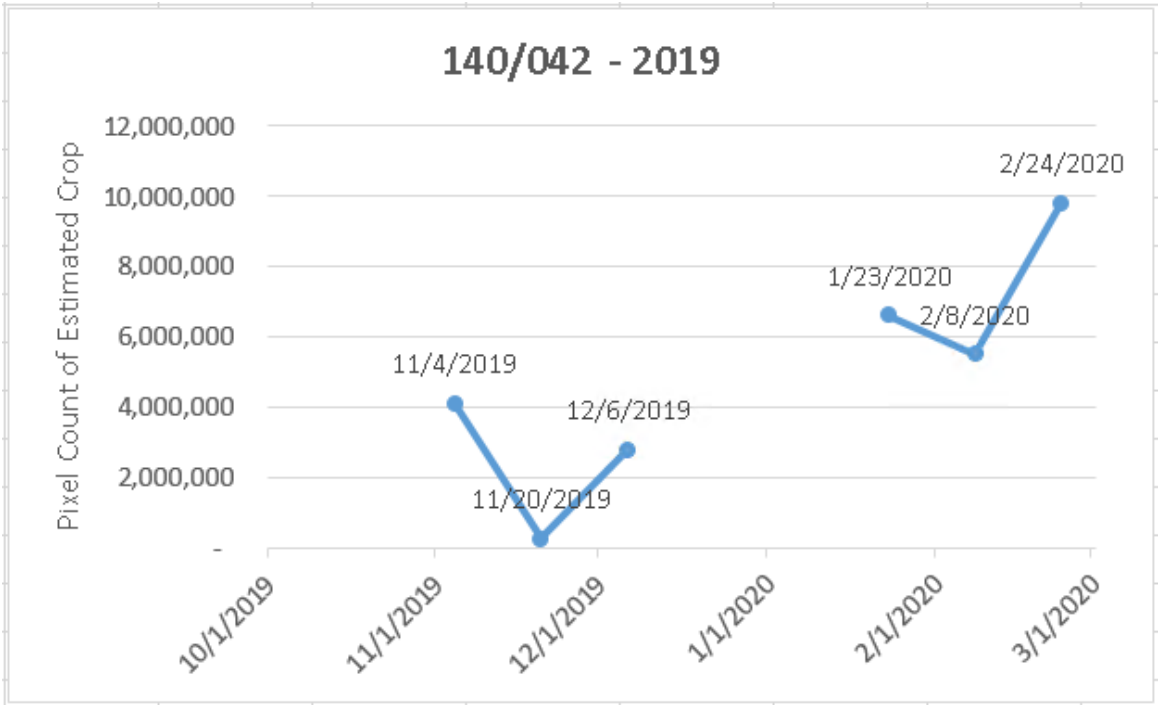


[29] Environmental Systems Research Institute (ESRI). 2020. ArcGIS Pro v. 2.5.0, geospatial software. Redlands, CA.

We then summed the count of pixels in each class to quantify the relative area by land cover type for each scene for the pre- and post-program years (2012 and 2019). We then compared the relative areas across dates within each programmatic year to determine when the green-up occurred. To exemplify the process, Figures C5 and C6 show an example of the areas of healthy vegetation for 2012 and 2019 respectively. The Figure C5 graphic shows a very large amount of vegetative growth at the end of the monsoon (10/15/2012), followed by a steep decline with very low vegetative growth by 12/2/2012. Note that missing dates due to a high percentage of clouds (>50%) or smoke are not included, and are indicated by a break in line. Vegetation growth then jumped from ~1 million pixels to 4 million pixels, indicating that the green-up period following sowing of crops probably occurred between 1/3/2013 and 2/4/2013. Figure C6 shows the plot for the post-program year (2019). The graphic indicates that the low amount of vegetation occurred by 11/20/2019, with green-up likely occurring by 12/6/2019. Comparing these dates, we can assume that the green-up date was at least 1 month earlier in the post-program period than the pre-program period.

Figure C5. Graph of the total count of pixels (area) classified as crop by date for the 2012/2013 season for a single Landsat scene (Path: 140, Row: 041). Gaps in the line indicate missing or non-useful imagery (e.g., due to cloud cover or smoke).

Figure C6 Graph of the total count (area) of pixels classified as crop by date for the 2019/2020 season for a single Landsat scene (Path: 140, Row: 041). Gaps in the line indicate missing scenes due to unusable imagery (e.g., greater than 50% cloud cover or obscured by smoke).



This process was repeated for each of the scenes across the study area. The full results for each scene and date (individual graphs) are provided in Appendix D (which is organized by program year and scene for comparison), but summarized in Table C2 below.

Individual scene comparisons (E-W and N-S) are shown in Table C2 (refer to Figure C1 for location of Landsat scenes). Table C2 indicates calendar date of lowest healthy vegetation cover and earliest date of green-up based on area summaries from classified imagery. The final column indicates estimated change in green-up date between two periods, where possible.

Table C2. Summary of change in green-up dates between pre- and post-programmatic growing seasons (2012 and 2019)

Landsat scene number (Path/Row)	Region	Latest date of low area prior to green-up		Date of green-up		Estimated change in green-up date
		2012	2019	2012	2019	
143/041	Uttar Pradesh	12/7	12/11	2/9	1/28	Inconclusive due to data gaps
142/041	Uttar Pradesh	11/30	12/4	2/18	2/6	Inconclusive due to data gaps
141/041	Bihar	12/9	11/27	2/11	3/2	Inconclusive due to data gaps
142/042	Uttar Pradesh	1/1	12/20	2/18	2/6	Inconclusive due to data gaps
141/042	Bihar	1/10	11/27	2/11	2/15	Inconclusive due to data gaps
140/042	Bihar	1/3	11/20	2/4	12/6	Green-up in 2019 likely at least one month earlier
139/042	Bihar	1/12	1/16	3/1	2/1	Inconclusive due to data gaps
142/043	Bihar	1/1	12/20	2/18	1/21	Inconclusive due to data gaps
141/043	Bihar	1/10* or 1/26	11/27	1/26* or 2/11	2/15	Inconclusive due to data gaps
140/043	Bihar	1/19* or 2/4	11/4	2/20	11/20* or 1/23	Unclear, but 2019 could be at least two months earlier
139/043	Bihar	11/25	12/31	1/12	1/16* or 2/1	Inconclusive due to data gaps

*Indicates difficulty in determining respective date.

Conclusion and Recommendations

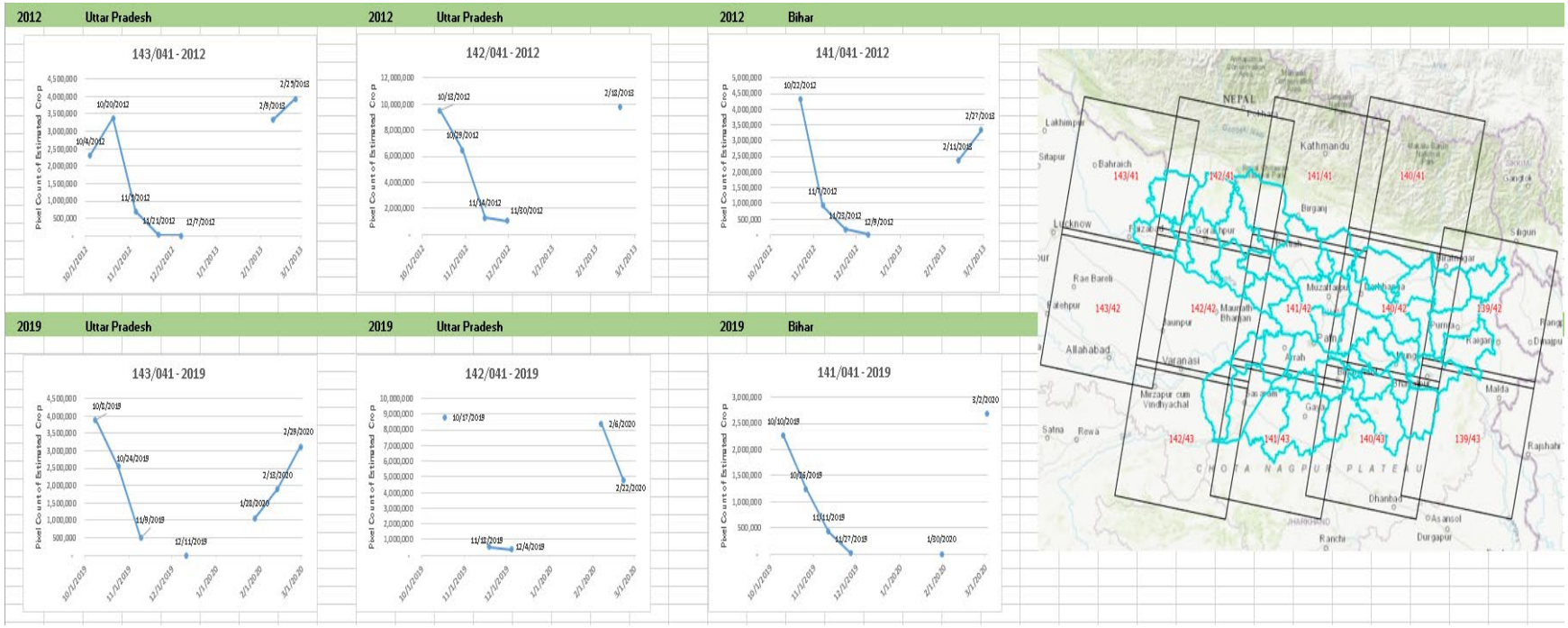
Overall, we were unable to determine whether there were changes in the green-up date between the pre- and post-programmatic years, primarily because of limitations in obtaining a temporally continuous set of imagery unobscured by clouds or smoke. This was made more challenging by the 16-day revisit time of the Landsat satellite, but that was unavoidable, because the Landsat satellite is the only global moderate-resolution imagery that is publicly available for these periods. While other data sets such as MODIS provide daily imagery covering the same periods, their resolution is substantially lower, and that can obscure the signal coming from the smaller-sized fields that predominate in the area. We also found that it is important to use a vegetative index that can be implemented across scenes and time periods – otherwise, it is difficult to assess whether the change is due to changes in atmospheric conditions or actual change in land cover.

However, we feel that our technique demonstrated the possibility of determining the change in green-up date between two time periods using vegetative indexes, should suitable imagery be available. Given that there are now satellites capturing multispectral imagery at five-day intervals (Sentinel), or even daily (e.g., Planet), at moderate resolution or at high resolution (~3.5 meters), it is likely that a nearly continuous set of imagery across the study area could be obtained – although in the case of Planet imagery, it is not freely available. The more-frequent revisit times also could also improve the ability to discriminate date changes at smaller time intervals. Under ideal circumstances, changes in green-up dates could be resolved to approximately two week intervals.

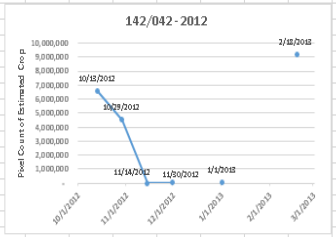
Lastly, while it is likely that future analysis can determine the change in green-up dates, determining that the change is due to the program and not some other environmental (monsoon dates, pests, drought, etc.) or economic variability can be challenging. In fact, this analysis appears to show some land cover changes associated with the date that the monsoon ended. Therefore, to better determine causality, future analysis will need to compare program and non-program areas for change and make use of enhanced on-the-ground survey information. Additionally, an analysis that covers a large number of years will increase the probability that trends are due to programmatic influences rather than environmental factors.

Appendix D: Geospatial Graphs

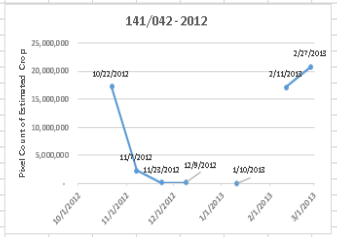
Graphs showing the area of healthy vegetation by date for all Landsat 7 scenes covering the analysis area. Landsat scenes are denoted by Path and Row number.



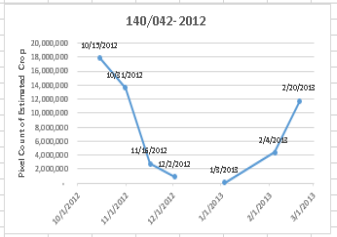
2012 Uttar Pradesh



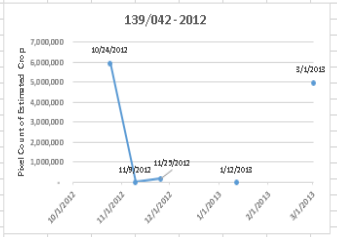
2012 Bihar



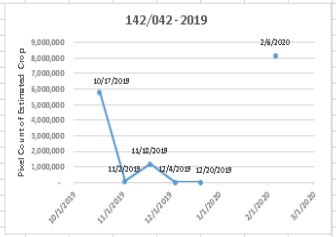
2012 Bihar



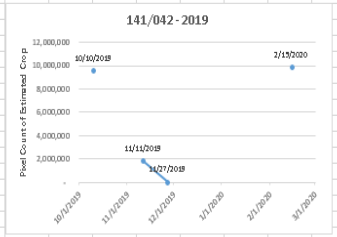
2012 Bihar



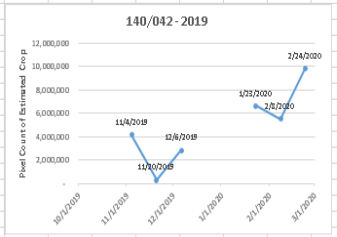
2019 Uttar Pradesh



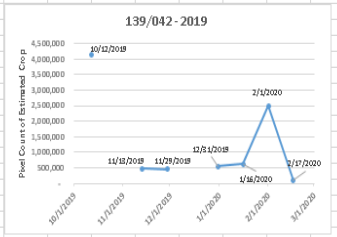
2019 Bihar



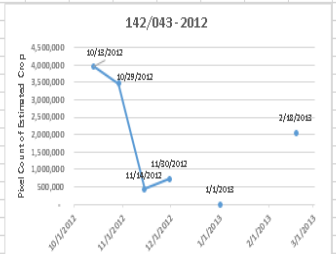
2019 Bihar



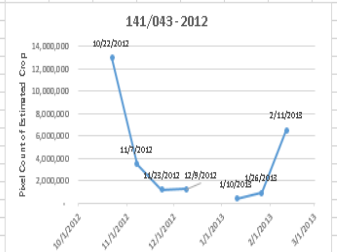
2019 Bihar



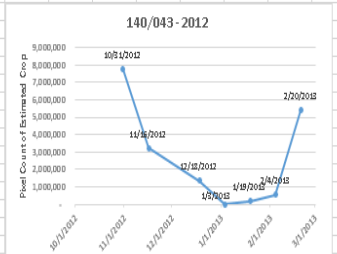
2012 Uttar Pradesh



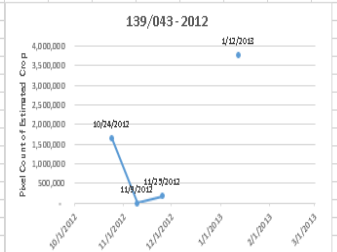
2012 Bihar



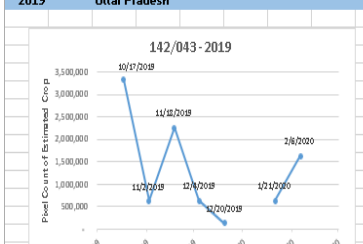
2012 Bihar



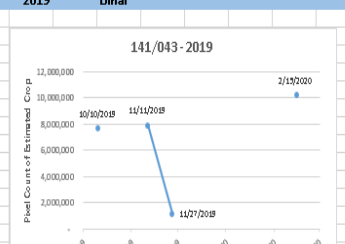
2012 Bihar



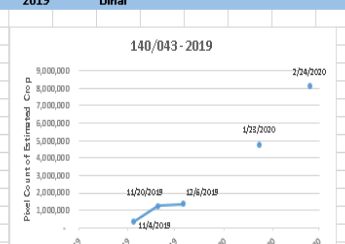
2019 Uttar Pradesh



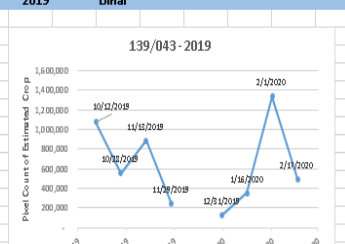
2019 Bihar



2019 Bihar



2019 Bihar



Appendix E: Online Survey Results

Respondent Characteristics

Table E1. Which of the following grants were you involved in or are you most knowledgeable about? (Select one)

Grant	Frequency	Percentage
African Cassava Agronomy Initiative (ACAI)	34	30%
Cereal Systems Initiative for South Asia (CSISA) Phase 2 (2012-2015)	4	4%
Cereal Systems Initiative for South Asia (CSISA) Phase 3 (2015-2020)	17	15%
N2Africa Phase 1 (2009-2013)	1	1%
N2Africa Phase 2 (2014-2019)	20	18%
Sustainable Banana Productivity in East Africa (SBPEA)	21	18%
Taking Maize Agronomy to Scale in Africa (TAMASA)	17	15%
Total	**114**	**100%**

Table E2. What was your role with the grant? (Select one)

Role	Frequency	Percentage
Agricultural extension/service delivery	37	33%
Agronomist/researcher	57	50%
Communications	5	4%
Management/operations/finance	6	5%
Other	9	8%
Total	**114**	**100%**

Table E3. What was the role of your organization with the grant? (Select one)

Type of partner	Frequency	Percentage
Academic partner	13	11%
Government sector partner	33	29%
Lead/prime implementing grantee	30	26%
Non-profit sector partner	21	18%
Private sector partner	14	12%
Other	3	3%
Total	**114**	**100%**

Table E4. What country were you based in while working with the grant?

Country	Frequency	Percentage
Ethiopia	21	18%
India	21	18%
Kenya	7	6%
Nigeria	22	19%
Tanzania	19	17%
Uganda	18	16%
Other	6	5%
Total	**114**	**100%**

Table E5. How many years did you work with the grant?

Years	Frequency	Percentage
1 to 2 years	23	20%
3 to 5 years	79	69%
6 to 10 years	6	5%
Less than 1 year	5	4%
More than 10 years	1	1%
Total	**114**	**100%**

Target Users of Agronomy Research

Table E6. Were you involved in or are you familiar with any of the agronomy research activities conducted under the grant?

	N	%
No	7	6%
Yes	107	94%
Total	**114**	**100**

Table E7. Who were the main target users of the research activity you were involved in or are familiar with? (select all that apply)*

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Academic agronomists/scientists/researchers	15	48%	12	60%	11	58%	14	70%	13	76%	65	61%
CGIAR	8	26%	8	40%	5	26%	5	25%	8	47%	34	32%
NARES	16	52%	10	50%	12	63%	11	55%	14	82%	63	59%
Agricultural extension agents	25	81%	18	90%	15	79%	18	90%	13	76%	89	83%
Donors	2	6%	4	20%	4	21%	1	5%	2	12%	13	12%
Government sector agronomists/scientists	17	55%	12	60%	15	79%	12	60%	15	88%	71	66%
Non-profit sector	11	35%	7	35%	7	37%	5	25%	6	35%	36	34%
Policymakers	8	26%	10	50%	9	47%	7	35%	7	41%	41	38%
Smallholder farmers (<5 ha)	29	94%	16	80%	19	100%	19	95%	13	76%	96	90%
Medium-scale farmers (5-10 ha)	21	68%	15	75%	6	32%	17	85%	5	29%	64	60%
Large-scale farmers (>10 ha)	12	39%	14	70%	5	26%	10	50%	3	18%	44	41%
Other	1	3%	3	15%	3	16%	0	0%	3	18%	10	9%
Prefer not to answer	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=31, CSISA=20, N2Africa=19, SBPEA=20, TAMASA=17, and Total=107.

Table E8. In order of importance, please rank the main target users that you just selected for the research activity you were involved in or are familiar with?*

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Average ranking
Academic agronomists/scientists	4.06	5.15	4.16	5.50	6.06	4.99
CGIAR	2.10	2.85	0.95	1.15	3.65	2.14
Donors	0.29	0.95	0.89	0.30	0.76	0.64
Agricultural extension agents	8.42	8.75	7.00	8.65	8.35	8.23
Government sector agronomists/scientists	3.94	4.45	6.79	4.05	7.00	5.24
Non-profit sector	2.55	2.20	1.58	1.35	2.59	2.05
Policymakers	1.65	3.25	2.68	1.85	2.29	2.34
Smallholder farmers (<5 ha)	10.48	8.00	10.05	10.65	8.59	9.55
Medium-scale farmers (5-10 ha)	6.84	6.85	2.37	8.45	2.06	5.31
Large-scale farmers (>10 ha)	3.71	5.25	1.63	4.95	0.88	3.28
Other	0.26	0.80	1.63	0.00	1.53	0.84
NARES	4.13	4.20	4.68	4.20	7.29	4.90

*Rankings are calculated using the weighted average ranking method.

Research Prioritization and Demand

Table E9. To what extent do you think the research in which you were involved or familiar with met the needs of your most highly ranked target user? (Choose one)

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
All needs of the target user were met	4	13%	5	25%	0	0%	1	5%	0	0%	10	9%
Some of the needs of the target user were met, but not all	21	68%	10	50%	10	53%	12	60%	3	18%	56	52%
Nearly all needs of the target user were met	5	16%	4	20%	9	47%	5	25%	12	71%	35	33%
Very few of the needs of the target user were met	1	3%	1	5%	0	0%	2	10%	0	0%	4	4%
None of the needs of the target user were met	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Prefer not to answer	0	0%	0	0%	0	0%	0	0%	2	12%	2	2%
Total	**31**	**100%**	**20**	**100%**	**19**	**100%**	**20**	**100%**	**17**	**100 %**	**107**	**100 %**

Table E10. What do you think were the most important factors which influenced the prioritization of the research you were involved in or familiar with? (Select all that apply)*

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Needs assessment of beneficiaries	25	81%	15	75%	13	68%	17	85%	10	59%	80	75%
Expertise of the research team	19	61%	15	75%	9	47%	12	60%	11	65%	66	62%
Government priorities	8	26%	11	55%	6	32%	7	35%	7	41%	39	36%
Adequate funding for the research	14	45%	11	55%	9	47%	6	30%	6	35%	46	43%
Suggestions from the Bill and Melinda Gates Foundation	9	29%	9	45%	7	37%	7	35%	6	35%	38	36%
Interest from partners with existing dissemination networks	26	84%	12	60%	10	53%	5	25%	7	41%	60	56%
Agronomic constraints limiting productivity	23	74%	12	60%	16	84%	15	75%	13	76%	79	74%
Other	0	0%	4	20%	0	0%	0	0%	1	6%	5	5%
Prefer not to answer	0	0%	2	10%	0	0%	0	0%	1	6%	3	3%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=31, CSISA=20, N2Africa=19, SBPEA=20, TAMASA=17, and Total=107.

Table E11. In order of importance (with 1 being the most important), please rank the changes that you selected in the previous question.*

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Average ranking
Needs assessment of beneficiaries	5.87	5.10	4.47	6.00	3.94	5.08
Expertise of the research team	3.68	4.30	2.32	4.15	4.00	3.69
Government priorities	0.81	3.00	1.74	1.25	2.06	1.77
Adequate funding for the research	2.68	2.95	2.47	1.65	2.00	2.35
Suggestions from the BMGF	1.35	1.90	1.74	1.50	2.18	1.73
Interest from partners with existing dissemination networks	5.16	2.95	2.89	1.35	2.41	2.95
Agronomic constraints limiting productivity	4.35	3.50	5.21	5.15	5.47	4.74
Other	0.00	0.85	0.00	0.00	0.47	0.26

*Rankings are calculated using the weighted average ranking method.

Table E12. Do you think there was a clear understanding on how to find out if there was demand for the agronomy research conducted under the grant? (Choose one)

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
There was a good understanding on how to assess if there was demand	26	84%	17	85%	10	53%	12	60%	10	59%	75	70%
There was an average understanding on how to assess if there was demand	4	13%	2	10%	8	42%	6	30%	4	24%	24	22%
There was no good understanding on how to assess if there was demand	0	0%	0	0%	1	5%	2	10%	1	6%	4	4%
Prefer not to answer	1	3%	1	5%	0	0%	0	0%	2	12%	4	4%
Total	**31**	**100%**	**20**	**100%**	**19**	**100%**	**20**	**100%**	**17**	**100%**	**107**	**100%**

Farmer Decision Support Tools

Table E13. Are you aware of the development of these Decision Support Tools as part of the work of the grant?

	N	%
No	15	16%
Yes	78	84%
Total	**93**	**100%**

Table E14. On a scale of 1 (not adopted at all) to 5 (adopted widely), how would you rate the extent to which the Decision Support Tool(s) were adopted by farmers? (ACAI respondents only)

	1 (not adopted at all)	2	3	4	5 (adopted widely)	Not released (yet)	Prefer not to answer
Fertilizer Blending decision support tool	0	2	4	6	1	7	14
Cassava Fertilizer Recommendation decision support tool	0	2	5	7	10	1	9
Best Planting Practice decision support tool	0	1	4	8	9	2	10
Inter-cropping decision support tool	0	4	5	5	10	2	8
Scheduled Planting and High Starch Content decision support tool	0	2	5	8	5	3	11
Total	**0**	**11**	**23**	**34**	**35**	**15**	**52**

Table E15. On a scale of 1 (not adopted at all) to 5 (adopted widely), how would you rate the extent to which the Decision Support Tool(s) were adopted by farmers? (TAMASA respondents only)

	1 (not adopted at all)	2	3	4	5 (adopted widely)	Not released (yet)	Prefer not to answer
Maize Seed Area decision support tool	3	1	1	1	0	2	8
Maize Variety Selector decision support tool	2	3	1	0	0	6	4
Nutrient Expert decision support tool	0	3	6	3	1	1	2
Total	5	7	8	4	1	9	14

Table E16. What do you think are the most important barriers to increasing the adoption of Decision Support Tools by farmers? (select all that apply)*

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Lack of participation from the private sector	13	38%	9	75%	0	0%	8	50%	5	29%	35	36%
Limited reach of dissemination networks	18	53%	8	67%	0	0%	11	69%	10	59%	47	48%
Limited understanding of farmers on how to operate Decision Support Tools	20	59%	10	83%	0	0%	16	100%	6	35%	52	53%
Cost of accessing Decision Support Tools	9	26%	5	42%	0	0%	8	50%	4	24%	26	27%
Lack of adequate cellular networks	16	47%	7	58%	0	0%	5	31%	7	41%	35	36%
Limited quality of recommendations of Decision Support Tools	1	3%	7	58%	0	0%	7	44%	6	35%	21	21%
Other	6	18%	2	17%	0	0%	2	13%	4	24%	14	14%
Prefer not to answer	1	3%	1	8%	0	0%	0	0%	1	6%	3	3%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=34, CSISA=12, N2Africa=19, SBPEA=16, TAMASA=17, and Total=98.

Table E17. In order of importance (with 1 being the most important), please rank the barriers that you have selected in the previous question [selection of most important barriers to adoption of DSTs].*

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Average ranking
Lack of participation from the private sector	2.00	3.83		2.81	1.88	2.63
Limited reach of dissemination networks	3.32	3.67		4.19	3.59	3.69
Limited understanding of farmers on how to operate Decision Support Tools	3.59	5.33		5.81	2.12	4.21
Cost of accessing Decision Support Tools	1.41	1.58		2.56	1.18	1.68
Lack of adequate cellular networks	2.62	1.75		1.50	2.00	1.97
Limited quality of recommendations of Decision Support Tools	0.21	2.75		2.00	2.06	1.75
Other	1.24	1.17		0.69	1.65	1.18

*Rankings are calculated using the weighted average ranking method.

Geospatial Modeling

Table E18. Are you aware of the application of geospatial soil mapping under the grant?

	N	%
No	46	40%
Yes	68	60%
Total	**114**	**100%**

Table E19. To what extent have you seen a change in the number of applications for geospatial soil data in agronomy research?

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Increased significantly	4	16%	3	30%	2	29%	5	38%	3	23%	17	25%
Increased	12	48%	4	40%	1	14%	8	62%	6	46%	31	46%
Neither increased nor decreased	2	8%	0	0%	2	29%	0	0%	2	15%	6	9%
Decreased	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Decreased significantly	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Prefer not to answer	7	28%	3	30%	2	29%	0	0%	2	15%	14	21%
Total	**25**	**100%**	**10**	**100%**	**7**	**100%**	**13**	**100%**	**13**	**100%**	**68**	**100%**

Table E20. What do you think were the most important barriers in the application and scaling of geospatial soil data? (select all that apply)*

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Lack of accurate geospatial soil data	8	32%	4	40%	4	57%	7	54%	8	62%	31	46%
Costs of applications	8	32%	5	50%	3	43%	7	54%	3	23%	26	38%
Lack of providers trained in using geospatial soil data	10	40%	9	90%	5	71%	10	77%	7	54%	41	60%
Lack of applications for geospatial soil data	10	40%	4	40%	5	71%	2	15%	4	31%	25	37%
Other	3	12%	0	0%	1	14%	1	8%	2	15%	7	10%
Prefer not to answer	5	20%	1	10%	0	0%	2	15%	0	0%	8	12%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=25, CSISA=10, N2Africa=7, SBPEA=13, TAMASA=13, and Total=68.

Table E21. In order of importance (with 1 being the most important), please rank the changes that you selected in the previous question.*

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Average ranking
Lack of accurate geospatial soil data	1.28	1.80	1.57	2.08	2.85	1.91
Costs of applications	1.32	1.70	1.86	2.38	0.92	1.64
Lack of providers trained in using geospatial soil data	1.72	4.00	3.14	3.31	2.08	2.85
Lack of applications for geospatial soil data	1.60	1.30	2.86	0.54	1.31	1.52
Other	0.92	0.30	0.57	0.23	0.77	0.56

*Rankings are calculated using the weighted average ranking method.

Capacity Development

Table E22. Are you familiar with or have you been involved in efforts to develop the capacity of researchers or extension agents?

	N	%
No	15	13%
Yes	99	87%
Total	**114**	**100%**

Table E23. To what extent do you agree or disagree with the following statement: the grant strengthened the capacity of the regional or national agricultural research system (NARS) to conduct agronomic research.

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Prefer not to answer	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Strongly disagree	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Disagree	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Neither agree nor disagree	0	0%	0	0%	1	5%	2	11%	0	0%	3	3%
Agree	11	37%	3	16%	10	50%	6	32%	5	45%	35	35%
Strongly agree	19	63%	16	84%	9	45%	11	58%	6	55%	61	62%
Total	**30**	**100%**	**19**	**100%**	**20**	**100%**	**19**	**100%**	**11**	**100%**	**99**	**100%**

Table E24. What are changes that the grant could make to strengthen the capacity of agricultural researchers? (Select all that apply)*

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Additional training in research and analysis	26	87%	13	68%	14	70%	17	89%	10	91%	80	81%
Increase research budgets	21	70%	12	63%	11	55%	14	74%	8	73%	66	67%
Additional lab resources/instruments and other technical resources	18	60%	13	68%	15	75%	11	58%	6	55%	63	64%
Improve collaboration with key research institutes	24	80%	13	68%	16	80%	17	89%	10	91%	80	81%
Increased opportunities for learning exchanges	22	73%	19	100%	13	65%	18	95%	10	91%	82	83%
Align incentives for staff and research partners to reduce competition	10	33%	8	42%	5	25%	9	47%	2	18%	34	34%
Other	0	0%	1	5%	0	0%	0	0%	0	0%	1	1%
Prefer not to answer	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=30, CSISA=19, N2Africa=20, SBPEA=19, TAMASA=11, and Total=99.

Table E25. In order of importance (with 1 being the most important), please rank the changes that you selected in the previous question.*

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Average ranking
Additional training in research and analysis	5.30	3.37	3.70	4.95	5.09	4.48
Increase research budgets	3.97	3.05	2.35	4.16	4.00	3.51
Additional lab resources/instruments and other technical resources	3.10	3.05	3.25	2.95	2.18	2.91
Improve collaboration with key research institutes	4.10	3.21	3.65	4.37	5.27	4.12
Increased opportunities for learning exchanges	3.53	5.21	2.10	4.32	4.73	3.98
Align incentives for staff and research partners to reduce competition	0.73	1.32	0.75	1.11	0.27	0.84
Other	0.00	0.37	0.00	0.00	0.00	0.07

*Rankings are calculated using the weighted average ranking method.

Table E26. To what extent do you agree or disagree with the following statement: the grant strengthened the capacity of extension agents to disseminate and promote new farmer technologies and tools.

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Prefer not to answer	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Strongly disagree	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Disagree	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Neither agree nor disagree	0	0%	0	0%	3	15%	2	11%	1	9%	6	6%
Agree	12	40%	3	16%	10	50%	7	37%	7	64%	39	39%
Strongly agree	18	60%	16	84%	7	35%	10	53%	3	27%	54	55%
Total	**30**	**100%**	**19**	**100%**	**20**	**100%**	**19**	**100%**	**11**	**100%**	**99**	**100%**

Table E27. What are changes that the grant could make to strengthen the capacity of extension agents to disseminate and promote new tools for farmers? (select all that apply)

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Increase training on tools they are disseminating and promoting	28	93%	15	79%	14	70%	17	89%	9	82%	83	84%
Establish better strategies to incentivize extension agents to promote new tools	26	87%	16	84%	13	65%	16	84%	9	82%	80	81%
Involve private sector partners with more relevant business models	26	87%	14	74%	18	90%	13	68%	6	55%	77	78%
Increase linkages to input distributors	24	80%	15	79%	16	80%	11	58%	8	73%	74	75%
Increase opportunities for learning exchanges	23	77%	17	89%	9	45%	14	74%	8	73%	71	72%
Other	0	0%	1	5%	1	5%	2	11%	1	9%	5	5%
Prefer not to answer	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=30, CSISA=19, N2Africa=20, SBPEA=19, TAMASA=11, and Total=99.

Table E28. In order of importance (with 1 being the most important), please rank the changes that you selected in the previous question.*

	ACAI	CSISA	N2Africa	SBPEA	TAMASA	Average ranking
Increase training on tools extension agents are disseminating and promoting	5.17	3.84	2.95	4.58	3.91	4.09
Establish better strategies to incentivize extension agents to promote new tools	4.10	2.95	1.90	3.95	3.64	3.31
Involve private sector partners with more relevant business models	3.40	2.84	3.80	2.79	2.45	3.06
Increase linkages to input distributors	2.77	2.68	3.10	2.16	2.64	2.67
Increase opportunities for learning exchanges	2.70	3.32	0.80	2.95	3.36	2.63
Other	0.00	0.21	0.30	0.47	0.55	0.31

*Rankings are calculated using the weighted average ranking method.

Challenges

Table E29. What were the main challenges faced by the grant? (select all that apply)*

	ACAI		CSISA		N2Africa		SBPEA		TAMASA		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Funding constraints	11	32%	9	43%	10	48%	6	29%	3	18%	39	34%
Limited staff capacity	5	15%	13	62%	6	29%	5	24%	5	29%	34	30%
Management/operational challenges	7	21%	7	33%	6	29%	8	38%	6	35%	34	30%
Policies or regulations	6	18%	7	33%	6	29%	6	29%	2	12%	27	24%
Poor facilities or infrastructure	6	18%	6	29%	9	43%	10	48%	5	29%	36	32%
Weak collaboration and coordination	1	3%	3	14%	7	33%	4	19%	7	41%	22	19%
Weak partnerships	3	9%	1	5%	7	33%	6	29%	2	12%	19	17%
Weak private sector organizations	12	35%	5	24%	13	62%	7	33%	6	35%	43	38%
Weak public sector institutions	10	29%	5	24%	12	57%	6	29%	5	29%	38	33%
Other	4	12%	2	10%	1	5%	0	0%	2	12%	9	8%
Prefer not to answer	5	15%	4	19%	0	0%	1	5%	3	18%	13	11%

*Multiple response question. Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=34, CSISA=21, N2Africa=21, SBPEA=21, TAMASA=17, and Total=114.

Table E30. What were the main challenges faced by the grant?* (select all that apply)*

	Academic partner		Government sector partner		Lead/prime implementing grantee		Non-profit sector partner		Private sector partner		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Funding constraints	3	23%	18	55%	10	33%	5	24%	3	21%	39	34%
Limited staff capacity	4	31%	13	39%	9	30%	6	29%	2	14%	34	30%
Management/operational challenges	6	46%	11	33%	10	33%	6	29%	1	7%	34	30%
Policies or regulations	3	23%	13	39%	5	17%	4	19%	1	7%	26	23%
Poor facilities or infrastructure	4	31%	17	52%	10	33%	3	14%	0	0%	34	30%
Weak collaboration and coordination	2	15%	8	24%	7	23%	5	24%	0	0%	22	19%
Weak partnerships	2	15%	9	27%	4	13%	4	19%	0	0%	19	17%
Weak private sector organizations	5	38%	13	39%	16	53%	9	43%	0	0%	43	38%
Weak public sector institutions	4	31%	11	33%	14	47%	8	38%	1	7%	38	33%
Other	2	15%	1	3%	0	0%	4	19%	2	14%	9	8%
Prefer not to answer	2	15%	1	3%	0	0%	1	5%	8	57%	12	11%

*Multiple response question and responses disaggregated by grantee/type of partner.
*Percentages represent the fraction of the number of respondents by grant who choose the response item (N) over the total number of respondents by grant who answered the survey question. Number of respondents by grant who answered the survey question: ACAI=34, CSISA=21, N2Africa=21, SBPEA=21, TAMASA=17, and Total=114.

Appendix F: Agronomy Grant Document Review Template

Grant	Implementation period	Funding	Primary implementer	Principal investigator and contact information	Countries and specific areas	Crops	Main objectives	Main activities and approaches	Approach to assessing demand	Key successes	Key Challenges

1. **Technologies/use-cases targeted**
2. **Approach to defining/deciding on research priorities/use cases (Q7, 8)**
   - 2.1. Identified target users for research (Q7)
   - 2.2. Needs identified of target users and if those needs were met (Q7)
   - 2.3. Lessons or adaptations made on how research priorities/use cases were identified (Q8)
3. **Primary activities (by country if applicable) and approaches used**
   - 3.1. Research activities
   - 3.2. Technology delivery or extension support activities
   - 3.3. Policy activities
   - 3.4. Systemic approaches used (if any or how attempted systemic change)
   - 3.5. Other activities
4. **Results/achievements (by country if applicable) (Q1, 2, 4)**
   - 4.1. Technology delivery to target users (e.g., private sector, agricultural extension, farmers) (Q1, 4)
   - 4.2. Impact of the grant on the broader agronomy sector in the country (e.g., use of research products, institutionalization of agronomy recommendations) (Q2)
5. **Key products developed (studies, dissemination materials, decision-support tools, etc.) (Q3)**
   - 5.1. Global goods created and their use (Q3)
6. **Partnerships developed**

6.1.Research partnerships

6.2.Scaling partnerships

7. **Scale (scale achieved, approaches to scaling, challenges scaling) (Q12)**
8. **Sustainability (institutionalization, mainstreaming, approaches to sustainability, challenges) (Q12)**
9. **Implementation challenges (Q10)**
10. **Unintended consequences (positive or negative)**
11. **Lessons learned (Q12, 13, 14)**

    11.1.Sustainability

    11.2.Efficiency

    11.3.Scaling

    11.4.Mainstreaming

    11.5.Collaboration or coordination

12. **Documents with M&E data (including results frameworks, performance indicators, impact or performance evaluation results)**
13. **Remaining questions/topics to learn more about during country visits**

Appendix G: References

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