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SCALING UP OF AGRICULTURAL MACHINERY IN BANGLADESH

REVIEW OF SUCCESSFUL SCALING OF AGRICULTURAL TECHNOLOGIES

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E3 Analytics and Evaluation Project

CONTENTS

ACRONYMS AND ABBREVIATIONS

ACI	Advanced Chemical Industries Limited
AFP	Axial Flow Pump
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BFS	Bureau for Food Security (USAID)
BRRI	Bangladesh Rice Research Institute (GOB)
CGIAR	Consortium of International Agronomic Research Centers
CIMMYT	International Maize and Wheat Improvement Center
COP	Chief of Party
CSISA-BD	Cereal Systems Initiative for South Asia – Bangladesh
CSISA-MI	Cereal Systems Initiative for South Asia – Mechanization and Irrigation
DAE	Department of Agricultural Extension (GOB)
DR	Document Reviews
E3	Bureau for Economic Growth, Education and Environment (USAID)
FGD	Focus Group Discussion
FTF	Feed the Future
GAPs	Good Agricultural Practices
GD	Group Discussion
GOB	Government of Bangladesh
Ha	Hectares
HCD	Human Centered Design
HH	Household
iDE	International Development Enterprises
iDE-B	International Development Enterprises – Bangladesh
IR	Intermediate Result
IRAP	Intervention Results Assessment Plan
IRRI	International Rice Research Institute
JVA	Joint Venture Agreement
KII	Key Informant Interviews
LLP	Low-Lift Pump
LOA	Letter of Agreement
LSP	Local Service Provider
M&E	Monitoring and Evaluation

Metal	The Metal (Pvt.) Limited
MFI	Micro-Finance Institution
MRM	Monitoring and Results Measurement
MRP	Market Retail Price
MSI	Management Systems International
MT	Metric Ton
NGO	Non-Governmental Organization
PIO	Public International Organization
PSP	Private Sector Partner
PTOS	Power Tiller-Operated Seeder
PTOR	Power Tiller-Operated Reaper
QDSS	Quantitative Data from Secondary Sources
RFL	Rangpur Foundry Ltd.
SAAO	Sub Assistant Agricultural Officer (GOB DAE)
SLG	Savings and Lending Group
SPR	Self-Propelled Reaper
SW	Southwest
TMSS	Thengamara Mohila Sabuj Sangha (MFI)
USAID	Unites States Agency for International Development
ZOI	Zone of Influence

EXECUTIVE SUMMARY

This report provides summary findings and conclusions from a case study examining the scaling up of agricultural machinery services through commercial pathways in southwest (SW) Bangladesh from 2012 to early 2016. It is one of a series of studies looking at successful scaling up of agricultural innovations in developing countries. USAID's Bureau for Food Security (USAID/BFS) has commissioned the E3 Analytics and Evaluation Project[1] to conduct these studies as part of its efforts to scale up the impact of the Feed the Future (FTF) food security initiative. The goal of these studies is to produce lessons learned and ultimately guidance for USAID and its country Missions interested in integrating a commercial pathways approach to scaling up into their FTF project designs, procurements, and implementation. This overall research is designed to provide a better understanding of what types of innovations and country contexts are best suited to scaling up through commercial pathways, and what are the activities, strategies, and support necessary to facilitate that successfully.

Agricultural machinery services are being scaled up in the context of the USAID-funded Cereal Systems Initiative for South Asia – Mechanization and Irrigation (CSISA-MI). The initial objectives of CSISA-MI were to introduce and promote adoption of new agricultural machinery to smallholder farmers with the goal of increasing farmers' productivity and incomes. This was expected to occur primarily by increasing the incentives for farmers to plant wheat or maize on fallow land in the off season. It was also expected to have an impact on the productivity of the traditional summer rice crop and environmental benefits, e.g. decreased water usage and improved soil conservation. The strategy to achieve these goals was to use market actors and pathways to drive this process, principally large agricultural machinery manufacturers/distributors who were expected to produce or import selected new machines, and promote, distribute, sell and service them.

CSISA-MI is a partnership of two of the partners in CSISA, the International Maize and Wheat Improvement Center (CIMMYT) and iDE Bangladesh (iDE-B). CIMMYT's role was to provide technical expertise in cereals cultivation, especially in selecting appropriate machinery. iDE-B was primarily responsible for market facilitation; getting farmers and private supply chain actors to adopt the new machinery. CSISA-MI began implementation in summer 2013 and has only been operating for three years. As such, scale has not yet been reached though there has been a significant number of early adopters. It has been operating only in the FTF Zone of Influence in SW Bangladesh, Khulna Division, Barisal Division and a portion of Dhaka Division.

It has therefore not yet reached its full scale, though there have been a significant number of early adopters. USAID and the review team selected CSISA-MI as a case study largely because of the innovative approaches to scaling that have been adopted and implemented in this case, such as a flexible, adaptive management approach; willingness to change strategy in terms of crops, technology, and locations; and a close and successful partnership with private sector actors from the very beginning. Because of these innovative approaches, CSISA-MI has had important qualitative accomplishments in commercial sustainability on the part of machinery producers, service providers who bought the machines, and farmers buying machinery services.

The innovations currently being scaled up are three agricultural machines that are relatively new to Bangladesh. These are: (i) axial flow pumps (AFPs) which are used for irrigation from surface water sources and operated by separate diesel engines; (ii) power-tiller operated seeders (PTOS) which provide tilling, seeding and, in principle, fertilizing services; and (3) self-propelled reapers (SPRs) which

[1] The E3 Analytics and Evaluation Project is implemented by team lead Management Systems International, in partnership with Development and Training Services (dTS) and NORC at the University of Chicago.

cut field crops like rice, wheat, jute and possibly other crops like jute. In all three cases the introduction of new machinery was combined with a business model of using Local Service Providers (LSPs) to provide services to small farmers on the assumption that it was neither economic nor affordable for small farmers to buy their own machines. LSPs already existed in the FTF ZOI providing services with PTs.

Agricultural Machine Characteristics

The characteristics of the three machines that facilitated scaling up are:

- Upgrades of existing machines;
- Leveraged existing power sources (i.e., power tillers and diesels);
- Required little or no change in other agricultural practices or adoption of other inputs/services;
- Purchases prices that were affordable for farmers relative to their disposable incomes and financial resources;
- Had high potential use time (i.e., farmers could use them for multiple crops and during multiple seasons);
- Utilization by multiple crops and seasons i.e. high potential use time;
- Ability to generate significant cost savings that translated into rapid repayment periods;
- Relevant to cash crops and labor-intensive activities;
- Benefits immediately visible and tangible to farmers in terms of cost, labor and time savings.

The Bangladesh Context

There were a number of characteristics of the Bangladesh context that facilitated scaling up of these services.

- Bangladesh experiences significant labor shortages around agricultural peak planting and harvesting times.
- The majority of potential users raise multiple crops and have access to irrigation. They diversify their risk across seasons and crops while limiting the risk of relying solely on rainfed agriculture.
- Most farmers have a commercial orientation and generate a cash surplus. They can feed their families based on the summer rainy season rice production, so crops from other seasons are de facto cash crops and provide cash income.
- Bangladesh has a large installed base of power tillers and LSPs providing services. Farmers have pre-existing experience with mechanization and buying machinery services, and new agricultural innovations can build on the existing services.
- Bangladesh has a viable, growing, and relatively dynamic private agricultural machinery sector with a fairly extensive distribution system in place.
- A very dense network of micro-finance institutions already exists, and some already have experience with lending for agricultural machinery.
- There is no public or parastatal entity that produces and sells machinery at below-market prices.

By contrast, the role of the public sector and policy enabling environment was fairly limited and largely confined to the provision of some price subsidies for machinery purchasers.

Commercial Sustainability

CSISA-MI introduced many approaches to project design and implementation that facilitated commercially sustainable scaling up. Perhaps the most important ones were (i) its steadfast commitment to using a market approach and adaptive management to respond to market feedback and (ii) its explicitly adopting an S-curve approach, meaning targeting and building up a critical mass of early adopters that would trigger spontaneous diffusion and an acceleration of scaling up. These twin commitments, though sometimes challenging, showed up in a number of ways:

- An experimental, trial-and-error approach to what technology would work, primarily based on farmers' reactions and demand;
- Willingness to pivot on which crops, machines, farmers, and locations to target, despite the lead role of the International Maize and Wheat Improvement Center (CIMMYT), which had a commitment to supporting wheat, maize, and cereals generally;
- Insistence on having private sector partners (PSPs) in co-equal roles from the very beginning, including PSPs who invested significant cash up front;
- An ultimately successful partnership between a research, CGIAR institution and a market facilitation NGO, with crucial components of giving the NGO significant resources and independence;
- A virtuous spiral approach that simultaneously created supply and demand at three different parts of the value chain: companies to dealers, dealers to LSPs, and LSPs to farmers;
- Recognizing that farmers, LSPs, and the entire supply chain had to have (market) incentives to participate/adopt, and working to make the new innovations profitable for everyone while simultaneously mitigating risk;
- Balancing the use of free or subsidized products and services with the recognition that some subsidy was necessary to encourage early adopters to try something new;
- Developing a Monitoring and Results Measurement (MRM) system that focused on collecting sales and adoption data to inform choices regarding strategy and activities;
- Exploration and introduction of multiple, innovative marketing techniques beyond the usual demonstrations, including bringing in a professional marketing consultant;
- Starting with two PSPs and then expanding to multiple PSPs to increase competition and broaden and deepen the market; and
- Strengthening key parts of the value chain, particularly the marketing and sales capacity of PSPs and after-sales service and availability of spare parts.

Lessons for Donors

This experience has generated a large number of lessons for donors interested in integrating a commercial approach to scaling up innovations into their activities. The most important of these are:

1. Begin with multiple technologies that are field tested with farmers, LSPs and PSPs to ensure feasibility in the local context, desirability to the target audience, and viability in the market place. Utilize a Human-Centered Design (HCD) approach to narrow down the number of technologies based on market feedback and use the initial experience to profile what types of farmers, crops and locations are likely to be early adopters.
2. Partner with private sector companies from the project start and insist on a relationship where partners share risk and make a significant initial financial co-investment with the majority of risk and investment borne by the project. These proportions gradually shift to where the PSPs are carrying the majority of the risk and investment.

3. Start with 1-2 key PSPs attracted by first-mover advantages and then open it up to multiple partners to create proper signals, incentives, and deepen and broaden the market.
4. Consciously adopt a flexible, adaptive management approach to overall strategy, work plans and activities that is market driven, using a bottom-up approach rather than simply targeting numbers of demonstrations, farmer participants, etc. Avoid fixating on numerical targets that can undermine a project's bargaining position with PSPs. Work with PSPs to change the top down culture and create confidence in and spaces for staff to provide feedback.
5. Supplement traditional M&E systems with monitoring that generates and uses marketing and sales data to adjust activities, targeting, and work plans.
6. Do use price subsidies and co-funding of market and sales activities to improve the business case for the whole supply stream, and most important early adopters. Plan on phasing these out as critical mass is reached, depending on the speed of adoption.
7. Support demand and supply creation simultaneously in a virtuous spiral.
8. The right contracting mechanism is critical. It must combine fixed high level goals and some accountability with substantial flexibility for implementing partners on how to achieve them, Cooperative agreements seem to be the better format.
9. Market facilitation skills such as marketing, sales, HCD, and working with PSPs are more important than technical skills or expertize. Where desirable to have a partnership between one or more organizations in implementation, the market facilitation organization should be the prime or in the lead, while research organizations should be limited to technical support.

I. INTRODUCTION

A. Background and Context of this Report

USAID's Bureau for Food Security (BFS) and country Missions have been implementing the Feed the Future (FTF) food security initiative for five years. In many cases, innovations developed and introduced by FTF at small scale have since gone to scale or are in the process of doing so. At the same time, it appears that some innovations that potentially could have gone to scale have not done so, have not reached their full scale potential, or are not fully sustainable at scale.

There are many reasons for the unfulfilled potential of some of these innovations. A key reason is the focus projects often place on achieving the immediate outcomes and objectives defined in an activity solicitation and award/agreement, which can distract from engaging in the lower-return activities necessary to create and sustain scale. Another key reason for unfulfilled potential is that methods for scaling up through commercial pathways are often poorly understood and/or integrated into activity designs, procurements, and implementation plans. There is anecdotal evidence to suggest that USAID/BFS and Missions could do more in both scaling and sustainability by using commercial pathways.

In this context, USAID/BFS has commissioned the E3 Analytics and Evaluation Project[2] to conduct a study and synthesize five case studies to better understand how commercial pathways have been used successfully in the scaling up and sustainability of agricultural innovations in developing countries. The goal of this overall study is to produce lessons learned and ultimately guidance for USAID/BFS and Missions interested in integrating this scaling up approach into activity designs, procurements, and implementation. A particularly important goal is to develop a methodology that will allow USAID and its implementing partners to: (a) estimate the speed and level of adoption by farmers; (b) identify the time and resources required to create the institutional foundations and enabling environment that would allow for a transition to commercially driven and/or spontaneous scaling up and diffusion; (c) identify critical levels of initial adoption that would allow for such a transition; and (d) provide for general benchmarks to monitor progress and success in creating the foundations for and a transition to commercially driven and/or spontaneous adoption and scaling.

This overall study is designed to address five research questions:

1. Are there models using commercial innovation and growth mechanisms for bringing new agricultural technologies to scale in FTF countries?
2. What are the essential characteristics of innovations, value chains, and other spaces for identifying where commercial innovation growth and diffusion models are appropriate for reaching potential scale?
3. What determines the shape of the S-curve[3] (e.g., size of critical mass of adopters, speed and timing of technology adoption and diffusion, peak levels of scale reached), and how can these factors be estimated?
4. What types of activities are appropriate to implementing or facilitating a commercial scaling pathway? Examples may include strengthening value chains and distribution mechanisms, using

[2] The E3 Analytics and Evaluation Project is implemented by team lead Management Systems International, in partnership with Development and Training Services (dTS) and NORC at the University of Chicago.

[3] The S shaped curve is a curve commonly used to characterize the pathway over time of the number of adopters, based on the path breaking work of Everett Rogers and others in the diffusion of innovation. Rogers and others have noted that empirically adoption can be thought of as a normal distribution, a few very early adopters, a large number of early and middle adopters, and then a decreasing number of later adopters. When this normal distribution is graphed against time, it takes the shape of an S.

media and other communication forms, and leveraging and strengthening social networks and channels.

5. What are the implications of achieving scale and sustainability using commercial scaling pathways for USAID's project designs, procurement mechanisms, planning, budgeting, cost/benefit analysis, and monitoring and evaluation of FTF programs?

B. Purpose of this Report

This report examines the successful scaling up through commercial pathways of both agricultural and irrigation machinery and services in southwest Bangladesh. The report largely focuses on the role of the USAID-supported project Cereal Systems Initiative for South Asia–Mechanization and Irrigation (CSISA-MI), which was the key driver of scaling up in close partnership with several agricultural machinery companies. Because of the unusual and successful way in which both the USAID Mission to Bangladesh and the implementing partners executed this project, the case study looks to see what donor and implementing partner practices were useful in scaling up and may serve as a model for similar efforts with other technologies and countries.

C. Methodology Used

The approach developed by the review team for conducting these case studies is grounded in the spaces, drivers, and pathways analytical framework developed by Hartmann and Linn and the scaling up framework authored by Cooley and Kohl of Management Systems International (MSI). These frameworks detail the roles in which spaces, drivers, and pathways contribute to successful scaling. The term "space" is multidimensional and encompasses the fiscal/financial, political, policy (legal and regulatory), organizational, socio-cultural, agro-ecological, partnership,[4] and learning components that could affect scaling. Drivers are those factors or actors that move an innovation from pilot towards scale, including the individuals or organizations that lead the scaling up effort, their motivation and incentives, and how these interact with the characteristics of the innovation itself and the spaces or context. Pathways are the sector used to take the innovation to scale: the private and public sectors, donors, and other third parties or some combination thereof. This study assesses the respective roles played by each sector, with a special emphasis on the role of the private sector, i.e., the commercial pathway, as that is the primary focus of this research.

The components within this framework that the review team examined in terms of their role in scaling up the innovation were:

- **Characteristics of the innovation:** the package of components needed to be adopted; knowledge and physical input requirements for effective adoption and implementation; cost, complexity, and sophistication required; changes needed, if any, in farmers' existing agricultural practices; and the relationship to adoption of other innovations, whether complementary, substitutes, or pre-requisites.
- **Adoption drivers and results over time and space:** the reasons for adoption; variation in the degree of adoption and other patterns; socio-economic and demographic characteristics; and the role of different information sources in affecting adoption.
- **Business case for the innovation:** the costs, risks, and returns of adopting, producing, marketing, and distributing the innovation (or innovation package) relative to the motivations and incentives of potential adopters and other private actors in the value chain. In this case there were a number of relevant actors: agricultural machinery producers and importers,

[4] The partnership space looks at the potential organizations whose sponsorship and resources can be enlisted by the lead or driving organizations to support scaling up.

agricultural machinery dealers, local service providers, farmers, and after-sales service providers (mechanics and spare parts).

- **The external context or spaces:** In the case of agricultural and irrigation machinery and services in Bangladesh, a review of the initial data collected narrowed the relevant spaces to: the policy enabling environment; the upstream supply chain (production, imports, distribution); the downstream market; access to finance and credit; partnerships (Implementing Partners (IPs), IPs with private sector partners (PSPs), and the project with the USAID mission), the after-sales services support; the services supply chain; and the organizational capacity of the private sector.
- **Scaling up strategy and activities:** In the case of agricultural and irrigation machinery and services in Bangladesh, it turns out that the overall strategy for scaling up was adapted year by year by the implementing partners (in consultation with the USAID Mission) in reaction to market response. The review team narrowed its focus to activities by the USAID CSISA-MI project and its PSPs to: introduce the machinery to potential local service providers (LSPs) and persuade them to purchase/adopt; introduce farmers to the machinery services and persuade them to purchase services; develop subsidies and other risk mitigation efforts; and address gaps or otherwise strengthen the market system and external context that facilitated scaling up, such as PSP sales/marketing capacity, access to credit, and after-sales service and spare parts.
- **Potential scale of adoption (the market space):** In the case of agricultural machinery services in Bangladesh, this study looked at the number of farmers who could use the machinery and services given agro-ecological conditions, relevant crops in southwest Bangladesh, and the installed capacity of complementary agricultural machinery – diesel engines and power tillers.

The methodology for this case study involved four data collection techniques: documents reviews (DR), key informant interviews (KIIs), group discussions (GDs), and analysis of quantitative data from secondary sources (QDSS). The review team used these approaches to collect qualitative and quantitative data from a diverse and large number of stakeholders associated with agricultural and irrigation technology machinery and services in Bangladesh. Table 1 summarizes the sources, key spaces, and drivers for the data collected. Each cell notes whether relevant data was provided for a particular topic, ranked on a scale of 1 (X) to 4 (XXXX) as to the importance and utility of the information gathered.

TABLE I: DATA COLLECTION OVERVIEW

Data Source	Data Collection Methodology	Data Collected					
		Characteristics of the Innovation	Adoption Drivers & Results	Business Case	External Context	Scaling Strategy & Activities	Potential Scale & Output Markets
Advanced Chemical Industries (ACI) Motors Ltd.	KIIs	XX	XX	XXX	XXX	XXX	XXXX
Bangladesh Agricultural Development Corporation (BADC)	KIIs, DR	XXX	X		XX		X
Bangladesh Agricultural Research Institute (BARI)	KIIs	X	X		XXX	XX	XXX
Bangladesh Department of Agricultural Extension (DAE)	KIIs	X	XXX		XXX		XX
International Maize and Wheat Improvement Center (CIMMYT)	KIIs	XXXX	XX	XX		XXXX	XX
International Development Enterprises - Bangladesh (iDE-B)	KIIs, DRs	XXXX	XXXX	XXXX	XX	XXXX	XXX
Rangpur Foundry Ltd. (RFL)	KII	X	X	XXX	XX	XX	XXX
The Metal (Pvt.) Limited (Metal)	KII	XX	X	XXX	XX	XX	X
TMSS (microfinance institution)	KII		XX	XX		X	
Unites States Agency for International Development (USAID)	KII				X	XXX	X
Farmers' purchasing services	GDs	XXXX	XXXX	XXX	XX	X	X
Local service providers	GDs	XXXX	XXXX	XXX	XX	X	X
Machinery dealers	KIIs	XXX	XXXX	XXX	XXX	X	X
CSISA-MI field staff	GDs	XX	XXX	X	XX	XXXXX	X
Spare parts suppliers	KIIs	XX		XXX	XXX	X	
DAE field staff	GDs	XX	XXX	X	XX	XXXX	XXX

The data collection took place in Dhaka, where most of the participating organizations have national-level offices and operations, and in the Khulna and Barisal regions of southwest Bangladesh, where the FTF project is active, during a three-week period in April 2016. The review team spent five working days in Dhaka conducting KIIs with key donor, project, public sector, and PSP organizations. They then travelled to the FTF zone and conducted nine days of field research (KIIs and GDs) in key areas where adoption of new agricultural machinery is steadily growing. Lastly, they conducted two days of interviews in Dhaka before departing the country.

During the three-week period, the review team was able to interview a large number of stakeholders. This included: 7 GDs with LSPs and farmers using services with a total of 45 participants; 3 agricultural machinery companies (ACI, The Metal (Pvt.) Limited, and RFL); 10 machinery dealers in multiple locations; 2 public agricultural research organizations involved in mechanization research (BARI and BADC); 2 implementing partners (CIMMYT and iDE-B); 1 microcredit organization (TMSS); and the Government of Bangladesh (GOB) agricultural extension service partner (DAE) both at its headquarters in Dhaka and with field staff in SW Bangladesh. The review team also completed an exhaustive document review and conducted quantitative analysis. The team reviewed roughly 40 documents, with the majority obtained from implementing partners and the GOB.

D. Structure of the Report

Section II of this report provides background information on agricultural mechanization in Bangladesh. It begins with the history of the introduction of basic agricultural mechanization, particularly power tillers in the 1990s, up to the current introduction of three types of new machinery through of the CSISA-MI project. It explains the various mechanisms and institutions that the Government of Bangladesh has used over the years to support maize production by smallholders. It establishes the need for agricultural mechanization, looking at the labor shortages and environmental challenges facing farmers in southwest Bangladesh.

Section III describes the technologies promoted by CSISA-MI —the axial flow pump (AFP), self-propelled reaper (SPR), power tiller-operated seeder (PTOS), and bed planter. Section V describes the local service provider (LSP) business model, and Section IV considers what key characteristics facilitated or constrained adoption and scaling up of this technology and business model. A major theme of Section V is that some of these machines replace existing machinery while others replace hand labor; some are complementary to existing machinery and others are completely new. This section also discusses the business case for the various actors. It assesses the costs and benefits of each machine and machinery service. It also looks at the purported agronomic benefits, the economic case, and the perceived value and weaknesses of each machine.

Section VI looks at the potential scale that agricultural machinery and machinery services did and could have reached, i.e., the size of the actual and potential market.

Section VII describes the specific strategies and activities for adoption and scaling up of agricultural machinery services. As the primary driver of this effort was the USAID-funded CSISA-MI project, this is the optic for the strategy discussion. Because of its innovative use of adaptive management and monitoring indicators, we look at how strategy, activities, and tactics evolved along the way.

Section VIII describes additional "key spaces" within the project that have been integral to its design and success. These include the function, challenges, and lessons learned from the partnership between CIMMYT (a research organization) and iDE (an NGO specializing in market-based development); the monitoring and evaluation (M&E) for the project; partnerships with private agricultural machinery companies; the role and impact of the public sector; and the role of finance, credit, and subsidies. Also

discussed is the warranty, after-sales service, mechanics, and spare parts part of the agricultural machinery value chain and existing farmer organizations.

Section IX describes USAID's critical role in the success of the project, including its oversight strategies, the portfolio approach that has allowed it the flexibility to give CSISA-MI the time it needs to build the foundation for long-term success without intense pressure to hit numbers; and its collaborative partnership with the implementing partners.

Section X summarizes the main conclusions, and lessons learned from this case study. It focuses on addressing the overall research questions: the characteristics of the innovation itself, the context, and the strategy that facilitated or hindered scaling up and sustainability. Section XI provides lessons learned specifically for donors interested in scaling up agricultural innovations through commercial pathways.

E. Team Composition

The review team for this case study was led by Dr. Richard Kohl of MSI, who is an economist and internationally recognized expert on scaling up and has been working with USAID/BFS and Missions in improving scaling up strategies for FTF programs and innovations for the past two years. Additional writing, research, and logistical support was provided by Dina Robbins of MSI.[5] Interviews with Bangladesh government officials and private sector partners were arranged by Himanshu Dhungana of iDE-Bangladesh. Translation support and field logistics were provided by Md. Mandud-Ul-Haque of iDE-Bangladesh.

II. COUNTRY CONTEXT

A. Farmers and Farms in the Feed the Future Zone of Influence

Feed the Future estimates that in Bangladesh, 162 million people live in 56,977 square miles, a land area slightly larger than the size of Iowa.[6] In terms of its political-administrative structure, Bangladesh is organized into divisions (8), districts (64), upazillas, villages, and wards. About 10 percent of farmers own 50 percent of the arable land, while 60 percent are functionally landless, and often lease land from larger holdings. Two divisions, Barisal and Khulna, make up the FTF project zone of influence (ZOI) in southwest Bangladesh (Figure 1). (The FTF zone also includes the portion north of Barisal but south of Dhaka which is not visible on this map; this is basically everything south-west from Dhaka and across the river.)

Bangladesh has abundant access to fresh water. Irrigation is omnipresent with water being drawn from either rivers or tube wells. In southwest (SW) Bangladesh, there are several thousand secondary canals providing irrigation from rivers. Individual plots of land are small, averaging around one acre in size, though many farmers have multiple, non-contiguous plots. Rice farmers have been aggregated into large blocks of land that are irrigated by a block manager using surface water pumping. In southern Bangladesh, a significant proportion of land that is used for rice lies fallow during the dry season.

[5] Ms. Robbins is the spouse of one of the project leaders at CSISA-MI, Kevin Robbins. This relationship had no influence on the analysis or conclusions of this paper.
[6] Feed the Future Bangladesh 2011-2015 Multi-Year Strategy, February 2011

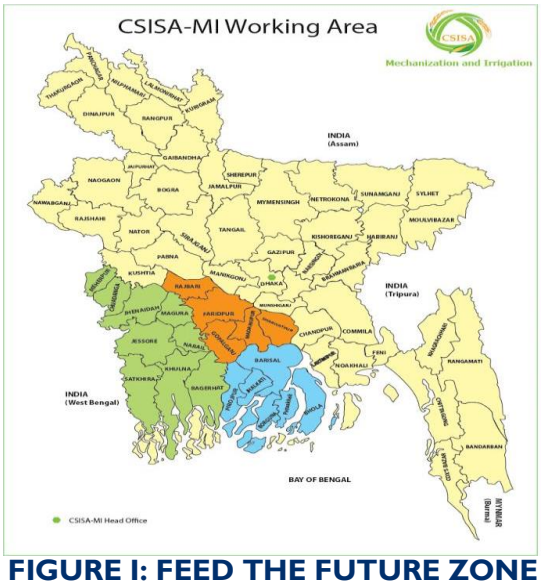


FIGURE I: FEED THE FUTURE ZONE OF INFLUENCE IN SOUTHERN BANGLADESH

In SW Bangladesh, on average farms are smaller, farming is less sophisticated, and mechanization is less advanced than in the more temperate northern regions. There are three types of farmers in this region: 1) large farmers/landowners, many of whom are absentee landlords; 2) medium size farmers who have roughly 2-5 hectares; and 3) smaller farmers with less than 2 hectares, many of whom lease some or all of their land as sharecroppers. The typical payment for sharecroppers is one-third of their crop.

In SW Bangladesh, there are several agricultural seasons depending on the crop, elevation of the land, and access to surface water or tube well irrigation. For example, farmers whose land is under water in the late fall or early winter cannot plant crops at that time.

TABLE II: SOWING AND HARVESTING PERIOD FOR KEY CROPS

Crop	Sowing Period	Harvesting Period
Broadcast aman rice	Mid-March to mid-April	Mid-November to mid-December
Transplanted aman rice	Late June to September	December to January
Boro paddy rice	Mid-November to mid-February	April to June
Wheat	November to December	March to mid-April
Onions	Beginning of October to early December	Late April to mid-June

Almost all farmers grow rice for their own consumption in the summer rainy or aman season. Even though rice productivity rates are relatively low, most farmers are able to grow enough rice in the aman season to feed their families and have a little left over to sell. As can be seen in Table III, both divisions and most of the individual districts in the target area are rice self-sufficient from the aman season alone.

TABLE III: AMAN RICE PRODUCTION AND FOOD SECURITY, 2013-14

Barisal

District	Hectares	% of Total Area	Yield per Hectare (MTs)	Production (000s MTs)	Rice Surplus/Deficit
Barisal	121,883	44%	2.0	243.8	-110.20
Barguna	92,763	51%	1.9	176.2	49.41
Bhola	176,171	52%	1.9	334.7	64.10
Jhalokati	43,027	61%	1.5	64.5	-39.44
Patuakhali	202,628	63%	1.7	344.5	110.55
Pirojpur	58,503	46%	1.7	99.5	-70.11
Total	**694,975**	**53%**	**1.8**	**1,263**	**4.32**

Khulna

District	Hectares	% of Total Area	Yield per Hectare (MTs)	Production (000s MTs)	Rice Surplus/Deficit
Bagerhat	81,374	21%	2.2	179.0	32.89
Chuadanga	39,193	33%	2.8	109.7	-2.03
Jessore	131,698	51%	2.4	316.1	42.39
Jhenaidah	83,824	43%	3.0	251.5	76.11
Khulna	96,915	22%	2.6	252.0	22.50
Magura	54,468	52%	2.3	125.3	34.35
Meherpur	23,569	31%	2.6	61.3	-10.17
Narail	35,330	36%	1.8	63.6	-7.85
Satkhira	92,020	24%	3.0	276.1	79.46
Total	**638,391**	**31%**	**2.6**	**1634.5**	**267.65**

Source: Statistical Yearbook of Bangladesh, 2011

Rice self-sufficiency from their aman season rice crop provides farmers with the food security to pursue more commercial farming the rest of the year. To generalize, most consider the horticulture crops, cereal, and jute crops they grow in the robi or boro season as primarily sources of cash income. In other words, most farmers are not merely subsistence farmers but have at least partly a commercial orientation. A significant number of farmers have small fish ponds, and there is an important and large commercial fish farming industry, called ghers. Farmers sell much of their fish, horticulture, and surplus cereals at local village markets, though some of their products make it to cities such as Khulna, Jessore, Barisal, and Dhaka, reinforcing the commercial orientation. The commercial orientation of farmers and their ability to earn surpluses were important foundations for their willingness to adopt machinery services.

Multiple seasons also have had important implications for timing and timeliness of sowing and harvesting (see Table II). For farmers to get their next season's crops, they have to harvest the previous seasons on time and quickly. This would allow them to plant aman rice, wheat or onions, and boro rice. Harvesting

boro rice on time is particularly important, as the harvest can run into the beginning of the monsoon rains that provide moisture for aman rice.

Both land and labor are fairly constrained in SW Bangladesh, limiting the possibilities for extensive growth in production, while also creating strong incentives for intensive growth. As noted in a recent study commissioned by CSISA-MI:

> *Cropland in Bangladesh has actually declined by 68,760 hectares per year (0.73%) since 1976, with consequent reductions in per-capita arable land availability (Hasan et al., 2013). Rice comprises 75% of total land area in Bangladesh, though the gains in production achieved during the Green Revolution, are near exhaustion (Pingali et al., 1997; Muragi, 2001). Food wastage is also rare in the predominantly subsistence farming economy. In other words, Bangladesh needs to produce more food without converting the little remaining amount of non-agricultural land to crop use, while concurrently easing farm labour requirements as it makes the transition into non-farm and increasingly profitable alternative forms of employment (Zhang et al., 2014).*[7]

Perhaps the single most important contextual driver has been the chronic and growing shortages of skilled agricultural labor in the area, despite the fact that many tenant farmers supplement their income through offering their labor. As can be seen in Table IV below, population growth over the ten-year period 2001 to 2011 in Barisal and Khulna was only 1.4% and 5.4%, respectively. This compares with over 11% for the country as a whole, showing the substantial outmigration of rural labor to urban areas and abroad. Migration is reinforced by the fact that, like many countries, young people in Bangladesh are increasingly unwilling or disinterested in becoming farmers, especially when it is a traditional highly labor intensive and low productivity activity.

The short periods of time during which any given crop can be harvested during each season mean that the competition for the available labor is great and labor costs peak. Many farmers find themselves waiting for days or even weeks for land preparation, planting, and harvesting labor; those with the fewest financial resources (who usually pay with a crop share rather than cash) wait the longest. Losses in crop production and income often result from fields not being harvested on time. While the windows for planting tend to be longer, total yields are significantly affected by every additional day that crops are in the ground, especially cereals. Labor shortages particularly affect many high-value added cash crops like onions and garlic, which require a fine till for planting and many people and days for the hand planting of the small bulbs.

[7] ADI, Market Study: Agricultural Machineries in Southern Bangladesh for the CSISA-MI Project. Final Draft Report. Dhaka, Bangladesh: January 2016

TABLE IV: AREA AND POPULATION OF MECHANIZATION AREA (SW BANGLADESH)

Barisal

Division or District	Total Land Area (km^2)	2001 Census (000s)	2011 Census (000s)	Change 2011-2001	Growth 2011/2001	Implied Paddy Rice Needs (000s MTs)
Barisal	2,784.0	2,336.0	2,324.0	-12.0	-0.51%	354.0
Barguna	1,831.0	848.0	832.8	-15.2	-1.8%	126.8
Bhola	3,403.5	1,703.0	1,776.8	73.8	4.3%	270.6
Jhalokati	706.8	694.2	682.7	-11.5	-1.7%	104.0
Patuakhali	3,221.3	1,460.8	1,535.8	75.0	5.1%	233.9
Pirojpur	1,277.8	1,111.0	1,113.3	2.3	0.2%	169.6
Total	**13,224.4**	**8,153.0**	**8,265.4**	**112.4**	**1.4%**	**1,258.9**

Khulna

Division or District	Total Land Area (km^2)	2001 Census (000s)	2011 Census (000s)	Change 2011-2001	Growth 2011/2001	Implied Paddy Rice Needs (000s MTs)
Bagerhat	3,959.1	1,579.0	1,476.1	-102.9	-6.5%	146.1
Chuadanga	1,174.1	1,007.1	1,129.0	121.9	12.1%	111.8
Jessore	2,606.9	2,471.6	2,764.5	292.9	11.9%	273.7
Jhenaidah	1,964.8	1,579.5	1,771.3	191.8	12.1%	175.4
Khulna	4,394.5	2,379.0	2,318.0	-61.0	-2.6%	229.5
Magura	1,039.1	824.3	918.4	94.1	11.4%	90.9
Meherpur	751.6	698.5	721.7	23.2	3.3%	71.4
Narail	968.0	698.5	721.7	23.2	3.3%	71.4
Satkhira	3,817.3	1,864.7	1,985.9	121.2	6.5%	196.6
Total	**20,675.4**	**13,102.2**	**13,806.6**	**704.4**	**5.4%**	**1,366.9**

Dhaka

Division or District	Total Land Area (km^2)	2001 Census (000s)	2011 Census (000s)	Change 2011-2001	Growth 2011/2001	Implied Paddy Rice Needs (000s MTs)
Fardipur	2,072.7	1,756.5	1,912.2	155.7	8.86%	189.3
Madaripur	1,144.9	1,146.3	1,212.2	65.9	5.75%	120.0
Gopalganj	1,468.7	1,165.3	1,172.4	7.1	0.61%	116.1
Rajbari	1,118.8	951.9	1,049.8	97.9	10.28%	103.9
Shariatpur	1,174	1082.3	1,155.8	73.5	6.79%	114.4
Total	6,979.1	6,102.3	6,502.4	400.1	6.56%	643.8
Grand Total	40,878.9	27,357.5	28,574.4	1,216.9	4.45%	2,829.1

Source: 2012 Statistical Yearbook of Bangladesh 32ND EDITION August 2013 Bangladesh Bureau of Statistics, Statistics & Informatics Division (Sid), Ministry Of Planning Government of The People's Republic Of Bangladesh Dhaka, Bangladesh

B. Impetus for the CSISA-MI Project

Prior to the start of the CSISA-MI project in 2011, land preparation was done by hand, animal traction, or increasingly power tillers owned by LSPs. Power tillers were good for rice and other cereals like wheat, but provided a shallow and coarse till, which is less than ideal for growing things like vegetables. Irrigation for crops and ghers was being provided by low-lift pumps (LLPs) which, though effective and inexpensive, were not as fuel and cost effective and efficient as newer models. On the harvesting side, while mechanical thresher services were widely available from LSPs supplementing the paddle threshers owned by many farmers, mechanical reapers were largely unknown outside of a handful owned by BADC or BARI and used for demonstration purposes. (The same was and remains true for combines, although a few entrepreneurs do come from other parts of the country to offer services.)

C. Existing Infrastructure for Machinery Sales and Adoption

Prior to the start of CSISA-MI and scaling of mechanization services, there was already significant presence of mechanization in Bangladesh, though it varied by region and crop. In terms of relevance to this study, the two major types of machinery present in SW Bangladesh are (i) two-wheel tractors or power tillers and (ii) centrifugal or low lift pumps (LLPs). Power tillers were initially introduced by the private sector in the 1980s, and adoption began to take off once the GOB lowered tariff rates to near zero in 1989. Initially their primary purpose was in helping in land preparation. As farmers gained more experience with power tillers over time, they realized that they could use power tillers year round for a multiplicity of tasks, especially hauling (with an attached wagon), general transportation, and providing power to drive other machinery in remote locations (usually a fanbelt). Since the early 2000s, their numbers have grown rapidly. The GOB does not yet have a national machinery census (data for the first one was collected in 2015 and is still being processed). According to interviews with the DAE team in charge of agricultural mechanization, there are currently approximately 700,000 power tillers in the whole country, and around 40 percent of those, or 280,000, are in SW Bangladesh. (Power tillers appear to be increasing by about 20,000 per year; prior to the start of CSISA-MI in 2011 there were probably around 420,000 in the country. CSISA-MI estimates that around 250,000 of those were added between 2007 and 2011, a rapid acceleration of adoption.[8])

LLPs are used throughout Bangladesh primarily for irrigation and for filling or emptying fish ponds. In SW Bangladesh, where surface water is abundant, they are particularly important, whereas in the rest of the country deep and shallow tube wells play a much more important role. In the Bangladesh context, pumps are distinguished from the engines that run them, and are physically separate. Engines can be diesel or electric, of varying horsepower (which relates to the amount of water that can be moved, which is usually determined by the diameter of the pump cylinder). While not commonly used, in principle the power force for pumps can also be supplied by hooking them up through a fan belt to power tillers.

One of the most important uses of LLPs is to irrigate rice in the dry or boro season. Several years ago the GOB encouraged small farmers to relocate into one contiguous area to systematize irrigation, or blocks, and put in place a system of block managers who own pumps and irrigate the entire block. Demand for pumping also comes from large commercial fish farming (called ghers) and smaller ponds owned by individual households, usually to sell in local village markets. Gher owners themselves usually own several LLPs. As of 2014, according to figures supplied by BADC, there were 171,041 LLPs being used to irrigate rice fields during the boro season, up from 77,000 in 2003-2004 – a compound annual

[8] Interviews with iDE-Bangladesh, and CIMMYT Bangladesh, Study into the Commercialization of Selected Agricultural Machines in Bangladesh, Report Prepared by International Development Enterprises (iDE), August, 2012. See especially Chapter 3, "Two-Wheel Tractor," pp 36-45.

growth rate of 8.3 percent.[9] As can be seen in Table V, there were about 46,000 pumps in SW Bangladesh, which is around one-quarter of the national total. In SW Bangladesh there was on average one LLP for 11.5 boro rice farmers, each of whom were cultivating around 0.38 hectares or 0.94 acres.

TABLE V: LOW-LIFT PUMPS IN BANGLADESH AND SW BANGLADESH, NUMBER OF FARMERS, AREA COVERED

Region	Total LLPs	Private		Operated by Diesel		Area Cultivated (ha)	# of Farmers Served	Implied Area per Farmer
Bangladesh	171,041	165,239	97%	160,624	94%	1,083,535	2,930,973	0.37
Barisal Division	13,294	11,544	87%	12,782	96%	127,000	368,581	0.34
Khulna Division	32,906	32,796	100%	32,586	99%	74,047	161,946	0.46
Total Barisal plus Khulna	46,200	44,340	96%	45,368	98%	201,047	530,527	0.38
Share of Bangladesh	**27%**	**27%**		**28%**		**19%**	**18%**	

Source: *Upazilla Wise Irrigation Equipment Used, Area Irrigated and Benefitted Farmer*, Unpublished document supplied by BADC

At the same time, with the growth of mechanization in Bangladesh, there has been the emergence of an agricultural machinery sector, which is discussed below in Section VIII. Bangladesh benefits from the strong innovative agricultural machinery industries in neighboring China, Vietnam, Thailand, and Japan and imports the majority of its machines and all of its power tillers and four-wheeled tractors. All these countries have similar rice-based agriculture, and therefore many of the machine models they have developed are potentially suitable for Bangladeshi agriculture. ACI, a large Bangladeshi conglomerate, was already importing and selling SPRs. PRAN-RFL, another large Bangladeshi conglomerate specializing in plastics manufacturing, was the largest importer of LLPs with roughly 80 percent of the market. Along with smaller regional and local companies, the result was established dealer networks and marketing and sales relationships throughout Bangladesh, though less dense in SW Bangladesh.

D. Impetus for the CSISA-MI Project

Prior to the start of the CSISA-MI project in 2011, land preparation was done either by hand, animal traction or increasingly power tillers owned by local service providers (LSPs). PTs were good for rice and other cereals like wheat, but provided a shallow and coarse till which is less than ideal for growing things like vegetables. Irrigation for crops and ghers was being provided by LLPs which, though effective and inexpensive, were not as fuel and cost effective and efficient as axial flow pumps (AFPs). On the harvesting side, while mechanical thresher services were widely available from local service providers (LSPs) supplementing the paddle threshers owned by many farmers, mechanical reapers were largely unknown outside of a handful owned by BADC or BARI and used for demonstration purposes. (The same was, and remains true, for combine harvesters; a few entrepreneurs do come from India or other parts of the country to offer services.)

In this context, USAID decided to fund and support a grant to a partnership between CIMMYT and iDE to improve agricultural mechanization in southwest Bangladesh, called the CSISA-MI project. Because

[9] This is dwarfed nationally by shallow tube wells at 1.5 million. Shallow tube wells are relatively less important in SW Bangladesh.

the project was funded in the context of USAID's Feed the Future (FTF) program, it targeted the FTF Zone of Influence (ZOI), i.e. only southwest Bangladesh. CSISA-MI was expected to help address many of the needs described above, such as labor shortages and low productivity. Labor shortages could be addressed by using machinery to reduce the number of workers required to perform formerly labor intensive tasks, especially land preparation and harvesting. Productivity could be improved through time and labor saving machinery such as power-tiller-operated seeders (PTOS), which help farmers to plant on time; and reapers and threshers, which help farmers to harvest on time and quickly. These machines had the potential of further increasing productivity by shortening the duration of production for some crops, allowing farmers to plant an additional one or even two crops per year on their field, thereby reducing the amount of time their land lay fallow.

Because CSISA-MI came out of the CSISA project, its primary focus was intended to be on cereals. There was particular hope on the part of CIMMYT and the Bangladesh government that introducing machinery that would bring down the costs or increase the productivity for farmers to grow wheat and maize, would encourage farmers who were only producing one crop of rice per year to grow wheat and maize on their fallow land in the rice off-season.

E. Purpose and Goals of CSISA-MI

The CSISA-MI project grew from work being done on agricultural machinery in Bangladesh under the larger CSISA-BD project. CSISA-MI was designed to build on that research and infrastructure to implement scalable, sustainable market interventions focused on helping farmers maximize use of the nearly 634,000 hectares of fallow land in the FTF ZOI in southern Bangladesh. The primary objectives were to increase productivity and lower the costs of growing wheat and maize on this land through access to mechanization services, thereby encouraging more production of those crops. While CSISA-MI understood that mechanization would benefit multiple crops, cereals were the primary targets, in line with the goals of CSISA-BD.

- **Strategic Objective 1:** To sustainably intensify and diversify agricultural production in southern Bangladesh through surface water irrigation to increase household income. This was largely based on the expected impact of AFPs.
- **Strategic Objective 2:** To sustainably transform agriculture in southern Bangladesh through broad-based access to agricultural mechanization services. CIMMYT and USAID saw the LSP business model and strengthening the agricultural machinery supply chain as important parts of this, in addition to the new technologies themselves.
- **Strategic Objective 3:** To develop new models for public and private institutions to support irrigation and agricultural mechanization in southern Bangladesh. While the primary pathway for scaling was expected to be through private sector partnerships, partnerships with Bangladesh Agricultural Research Council, BADC, and DAE to promote familiarity with machinery engineering, manufacturing, sales, distribution, and use in the field were also expected to be important in promotion and sales. Moreover, there was some expectation that Farm Business Advisors and DAE Sub Assistant Agricultural Officers (SAAOs) would become local advocates for the improved technologies, as well as outfitting mechanics and workshops to handle the maintenance and repairs.

F. Design, Contracting, and Funding of CSISA-MI

The details of how this project came to be funded by USAID are important because of potential lessons for donor design and procurement. CIMMYT and iDE approached USAID about funding such a project because of their experience in looking for and testing machinery under CSISA-BD. They did extensive preparatory work in the year prior to submitting the proposal, including identifying machines, lining up

potential partners, and preliminary advocacy and awareness building with relevant government agencies. USAID had money in its budget that had to be spent by the end of the year, and it funded CSISA-MI as a grant to CIMMYT. This was possible because of CIMMYT's status as a public international organization (PIO); grants to PIOs are a quick way to disburse money before the end of the fiscal year.

The key design element of CSISA-MI was the use of partnerships with large agricultural machinery companies. In these relationships companies would be expected to cover the capital investment costs of importing or producing machines. In turn, CISISA-MI would provide resources to subsidize prices to early adopters and to cost-share the costs of marketing and building initial awareness. The project design recognized that the introduction of new mechanization technology faced a number of simultaneity problems: dealers would not purchase machines from companies unless they felt there was demand from LSPs; LSPs would not purchase machines unless dealers made them available and farmers expressed demand for machinery services; farmers would not demand services unless they had been exposed to them first and the machines were then available in their local area. Accordingly, a key design element of the project was that demonstration and awareness-building efforts were simultaneously for dealers, existing or potential LSPs, and farmers.

III. CHARACTERISTICS OF THE INNOVATION

This section looks at the technology package or the innovation itself.[10] It describes each of the pieces of machinery introduced by the project, and explains what existing practices the machines replace. It assesses the costs and benefits of each machine and machinery service. It also looks at the purported agronomic benefits, the economic case, and the perceived value and weaknesses of each machine. The project intends that the adoption of new machinery is embedded in a business model whereby LSPs buy machines for their own use and to provide machinery services on a fee-for-service basis to other farmers (or purely as a machinery services business). Because of this, the technology is looked at from the perspective of LSPs and of service recipients, which are referred to as farmers even though nearly all LSPs are also farmers. As noted above, the FTF zone in Bangladesh is not homogenous, and cropping patterns, practices, and preferences vary across the different districts. Where relevant, these differences and how they affected the actual and perceived benefits of adopting the machines and machine services are noted.

A. The Nature of Innovation in CSISA-MI

The goal of CSISA-MI was to both introduce several new machines into the market for purchase, and simultaneously scale up a business model where a local service provider (LSP) provides machinery services to their community. The LSP model was based on the idea that it did not make financial or economic sense for most small farmers to buy their own machine. This is because first, most small farmers do not have the capital to be able to afford a machine; second, most small farmers do not have the land size to justify purchase of an expensive machine; and third, the machines are only useful for very short windows of time during the year.[11] Thus, the project hoped to identify key farmers with the capital, entrepreneurship, and business skills to buy a machine, which they would use on their own land and then use to provide services for a fee to their neighbors for the remainder of the relevant season. It also hoped to build on the fact that there was an existing level of LSPs providing pumping, threshing, and land preparation services.

[10] Information in this section was gathered through a combination of document review, interviews with CIMMYT and iDE machinery experts, and users themselves – agricultural machinery dealers, Local Service Providers, and farmers.
[11] This varies by machine, see below.

B. Process of Selecting Machinery for Scaling

Scaling up of agricultural machinery services in SW Bangladesh differs from many cases of technology scaling since the project made choices about the technologies implemented over time. In part this was by design, as the project was from the beginning intended to be market based, using feedback from potential adopters to improve the machine designs and, if necessary, drop or add machines as the needs of farmers and LSPs were discovered through time.

Another important element for selecting the machinery was the institutional priorities of the lead implementing partner, CIMMYT. CIMMYT was committed to increasing the cultivation of wheat and maize on fallow land in the robi seasons, and improving the productivity of those crops for farmers already growing them. This commitment was for two reasons: first, because CIMMYT as an institution is focused on wheat and maize, and second, because CIMMYT had a strong sense that it had promised wheat and maize to the USAID Mission in its initial grant proposal.

The choice of machines was also closely linked to the fact that the CSISA-MI project grew out of the CSISA-BD project, [12] also supported by USAID, CIMMYT, and iDE. A small but significant component of CSISA-BD was to encourage the promotion and adoption of cereals production in Bangladesh. CIMMYT, the International Rice Research Institute (IRRI), and other partners such as iDE spent several years proactively identifying machinery in China, Thailand, and Vietnam that might be relevant to the Bangladeshi context, as well as working with BADC to develop and test relevant machinery. The criteria for selection of these machines was, first, relevance to cereals production; second, that the machine made agronomic sense; and third and to a much lesser extent, that it made economic sense and was appropriate to farmer needs and market demand. Based on these criteria, the four machines—an AFP, an SPR, a PTOS attachment, and a bed planter—were selected to address the problems of labor shortages and low productivity.

C. The CSISA-MI Innovation Package

As discussed earlier in this section, CSISA-MI was committed from the very start to using (i) a commercial pathway and mechanism to achieve adoption, scaling, and sustainability of specific agricultural machinery and (ii) the LSP business model. It initially introduced four technologies, but soon dropped the bed planter (see Table VI). After their initial introduction, the AFP and PTOS both proved to be successful in that a number of LSPs adopted them and farmers purchased LSP services for them. The bed planter proved to be a failure and was discarded. Adoption of the reaper is an ongoing effort which has started to show success in Year 3 and has led to the introduction of an alternative reaper model, a power-tiller operated reaper (PTOR).

[12] The CSISA-BD project was a five-year initiative implemented primarily through a collaboration between three CGIAR member centers, IRRI, CIMMYT and WorldFish. The project aimed to increase household income, food security and livelihoods in impoverished and agriculturally-dependent regions of SW Bangladesh. A major focus of the initiative was the introduction and scaling of new cereal varieties, e.g. drought and saline-tolerant rice, accompanied by better agricultural practices.

TABLE VI: AGRICULTURAL MACHINERY INTRODUCED BY THE CSISA-MI PROJECT

Machine	Intent	Advantages	Disadvantages
Axial flow pump (AFP)	To replace existing centrifugal or low-lift pumps (LLPs)	• Can pump a greater amount of water over time than LLP • Lower fuel costs than LLP • Does not require priming	• More expensive • Shorter life span
Self-propelled reaper (SPR)	To cut grain crops such as rice, wheat, and maize	• Has potential for other crops, including sesame, rice and possibly jute • Saves labor and time	• Still requires a labor gang for gathering and threshing • High price point
Power tiller-operated seeder (PTOS)	Land preparation: tilling, fertilizing and seeding	• Provides a much finer till of soil than the power tiller alone • Can insert seeds and fertilizer • Provides facilitates line sowing and strip tillage	• Fertilizer box does not work well with types used in Bangladesh
Bed Planter	Facilitates line sowing and the creation of beds	• Makes the raised bed necessary for planting rows of maize and wheat • Beds increase water retention and reduce irrigation needs, as well as prevent some pest problems (rodents)	• Heavy and cumbersome to use • Currently built to order – not commercially available •

Source: Inteviews with CIMMYT and IDE-B staff

D. Key Characteristics of the Machines and Services That Facilitated Scaling

Based on the findings of this study, the CSISA-MI experience suggests that key characteristics of the innovations facilitated adoption. The innovations:

1. Replace or upgrade existing technology;
2. Can be easily grafted onto existing technology;
3. Have low price points relative to farmers' income and financial resources;
4. Have multiple uses, i.e., are applicable to multiple crops and seasons;
5. Require little or no change in existing agricultural practices;
6. Are easy to use with minimal training;
7. Are applicable to relevant cash crops, e.g., onions and jute;
8. Enable farmers to repay loans or recover investments in a short period of time;
9. Reduce time/amount of hired labor needed, providing significant labor savings;
10. Allow for earlier planting and harvesting, providing significant time savings;
11. Impact timeliness, allowing for longer growing seasons, facilitating transitions to the next season, and enabling farmers to avoid harvesting during the rain;
12. Offer significant cost savings to LSPs; and
13. Offer significant cost savings to farmers.

Table VII provides an assessment of how each of the machines introduced does on these thirteen criteria. Thus AFPs and PTOSs met most or all of these criteria and have been the easiest to scale up whereas the Self-Propelled Reaper (SPR) met fewer of them.

The characteristics that posed challenges for scaling were that all the machines required proper maintenance, access to spare parts, and servicing in order to function properly and create value for farmers. These characteristics required some training for proper use on the part of the farmers, follow-

on support from distributors/dealers, and strengthening of the spare parts supply chain. The advantage of the machines is they were more expensive than the innovations of new seeds and varieties, creating higher absolute and relative margins for those selling the machines, making providing the machines and services viable for the private sector.

Lastly, the necessity of going all-in on the investment up front (versus being able to try a small amount first to see how it works as with seeds or fertilizer), is a significant factor in the perception of risk for LSPs. The LSP model shifted this risk from farmers to service providers, and to those financing machinery purchases by LSPs. In this latter regard, financial intermediaries stated in interviews that they do much greater due diligence on agricultural machinery loans versus working capital loans for an agriculture campaign, because of the greater value and duration of the loan. These findings suggest that the characteristics of risk that affect the initial adoption and scaling of innovations are: the absolute cost relative to financial resources; the length of the potential repayment period; and the number of days/uses of the machine over the course of the year. On balance, the high cost of machinery cuts two ways.

TABLE VII: ASSESSMENT OF CHARACTERISTICS OF INDIVIDUAL AGRICULTURAL MACHINERY TECHNOLOGIES

Criteria	AFP	PTOS	SPR	PTOR
1. Replace or upgrade existing technology	Yes, LLPs	Yes, power tillers as tillers	No, no previous mechanization	No, no previous mechanization
2. Easily grafted onto existing technology;	Yes, diesels	Yes, power tillers	No	Yes, power tillers
3. Low price points	Cheapest of the four, but more costly than LLPs	Moderate	No	Moderate
4. Have multiple uses/length of use	Yes, fish, rice, any irrigation	Yes, wheat, maize, jute, onions		
5. Require little or no change in Existing agricultural practices	Yes	Yes, but not line planting	No	No
6. Easy to use with minimal training	Yes, just installation	Yes	Somewhat	No, takes time to master
7. Applicable to relevant cash crops	Yes, fish, boro rice	Yes (see above)	Somewhat	Somewhat
8. Enable farmers to repay loans or recover investments in short period of time	Yes, usually no loans needed	Can be repaid in 1-2 seasons	No, requires 2 years	Remains to be seen, probably
9. Significant labor savings	No	Yes	Yes, but still requires threshing	Yes, but still requires threshing
10. Significant time savings	Yes	Yes, especially onions, garlic	Yes, but…	Yes, but…
11. Impact on timeliness	For rice farmers	Yes	Yes	Yes
12. Significant cost savings to LSPs	Yes	Yes	Yes	Yes
13. Significant cost savings to farmers	No	Yes	Yes	Yes

Tables VII through X provide breakouts of scaling up to date, disaggregated by crop, machine, and year. The most number of farmers using machinery services have been in onions and rice, not surprising as the former is the most valuable and remunerative cash crop, while rice cultivation is the most widespread. It does appear the cash earnings potential of crops plays a critical role, at least in early adoption.

TABLE VIII: NUMBER OF FARMERS ADOPTING AGRICULTURAL MACHINERY SERVICES, BY YEAR, MACHINE, AND CROP

Year 1: 2013/14

Farmers	Wheat	Maize	Rice	Lentil	Onion	Jute	Garlic	Mungbean	Fish	Total
AFP	0	0	3,676	0	0	0	0	0	127	3,803
PTOS	97	9	0	272	412	169	156	91	0	1,206
SPR	11	0	56	0	0	0	0	0	0	67
Total	108	9	3,732	272	412	169	156	91	127	5,076

YEAR 2: 2014/15

Farmers	Wheat	Maize	Rice	Lentil	Onion	Jute	Garlic	Mungbean	Fish	Total
AFP	0	0	2,607	0	0	0	0	8	345	2,960
PTOS	187	21	6	79	1,159	1,186	73	41	0	2,752
SPR	1,883	0	1,188	0	0	0	0	0	0	3,071
Total	2,070	21	3,801	79	1,159	1,186	73	49	345	8,783

Year 3: 2015/16

Farmers	Wheat	Maize	Rice	Lentil	Onion	Jute	Garlic	Mungbean	Fish	Total
AFP	38	1	2,481	0	0	0	0	29	397	2,946
PTOS	3,849	52	16	1,823	10,280	1094	1,472	389	0	18,975
SPR	139	0	1870	0	0	0	0	0	0	2,009
Total	3,653	0	1,872	1,818	10,279	0	1,472	114	132	23,930

All Three Years

Farmers	Wheat	Maize	Rice	Lentil	Onion	Jute	Garlic	Mungbean	Fish	Total
AFP	38	1	8,764	0	0	0	0	37	869	9,709
PTOS	4133	82	22	2174	11851	2449	1701	521	0	22,933
SPR	2033	0	3,114	0	0	0	0	0	0	5,147
Total	5831	30	9,405	2169	11850	1355	1701	254	604	37,789

All Three Years, Percent by Machine Type

Farmers	Wheat	Maize	Rice	Lentil	Onion	Jute	Garlic	Mungbean	Fish	Total
AFP	0.39%	0.01%	90.27%	0.00%	0.00%	0.00%	0.00%	0.38%	8.95%	100%
PTOS	18.02%	0.36%	0.10%	9.48%	51.68%	10.68%	7.42%	2.27%	0.00%	100%
SPR	39.50%	0.00%	60.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100%
Total	15.43%	0.08%	24.89%	5.74%	31.36%	3.59%	4.50%	0.67%	1.60%	100%

TABLE IX: FARMERS AND HECTARES USING MACHINERY SERVICES

	Number of Farmers				Number of Hectares			
	Year 1 2013/14	Year 2 2014/15	Year 3 2015/16	Total	Year 1 2013/14	Year 2 214/15	Year 3 2015/16	Total
AFP	3,913	3,018	7,368	14,299	1,789	1,450	3,878	7,117
PTOS	1,256	2,792	18,955	23,003	553	1,597	7,166	9,316
SPR	350	3,071	3,432	6,853	71	1,205	6,188	7,464
Total	5,519	8,881	29,755	44,155	2,413	4,252	17,233	23,898

Source: CSISA-MI

TABLE X: ADOPTION OF AGRICULTURAL MACHINERY, HECTARES PER FARMER

	Implied Hectares per Farmer			
	Year 1 2013/14	Year 2 2014/15	Year 3 2015/16	Average
AFP	0.46	0.48	0.53	0.50
PTOS	0.44	0.57	0.38	0.41
SPR	0.20	0.39	1.80	1.09
Total	0.44	0.48	0.58	0.54

Source: CSISA-MI

The data in Table X shows that farmers are using machinery largely for relatively small areas, as was intended. Average size for all machines over the three years was around 0.35 ha (almost an acre), but this number is artificially low because the data for Year 3 reflect a partial year; for the first two years it is 0.46 ha, or a little more than an acre. The range of hectares per farmer ranged from 0.20 to 0.57 ha, suggesting that most service users are, as intended, smaller farmers.

1. Axial Flow Pump

AFPs are used primarily to pump water. They replaced what are called low-lift pumps (LLPs) or centrifugal pumps. Both LLPs and AFPs do not include engines, but are operated by attaching them to a diesel engine or a power tiller. In practice, most farmers use diesel engines, and many more farmers own one or more diesel engines than own power tillers. The size of the engine required depends on the diameter of the AFP: 6-inch AFPs use 12-16 hp engines, and 4-inch AFPs can be operated with 8 hp engines. The original AFP imported from Thailand was a 4-inch model.

AFPs were the easiest of the selected machinery to introduce and scale to date. Their major advantages were their low purchase price (BDT 18,000–25,000) (many farmers do not require financing to buy the machines), their use at multiple times of the year (especially for gher owners), and their relevance to the two most important crops to Bangladesh (i.e., rice and fish). Moreover, they were easier to use than LLPs, and perhaps most importantly, they are replacing an existing machine (the LLP) within an established market system.

The pumps are not without their problems however. While the training was brief, there was an initial learning curve for farmers to use them properly. Block managers and gher owners needed help being shown how to set up and install the pumps; many prefer to create fixed installations rather than have mobility. The initial AFP from Thailand was made out of too thin a gauge of metal, reducing its durability as compared to the LLPS it was replacing, and the company who imported these pumps brought mostly 4" tube diameter pumps, but many gher owners and rice block managers wanted 5" and 6" diameter pumps (some gher owners prefer 8"+). These limitations on the initial machines prompted better market segmentation, redesigns and local manufacture on the part of some private sector partners.

The other drawback of AFPs is that they cannot be used throughout Bangladesh. AFPs are limited to areas where pumping is confined to surface water and the pumping height is 3 meters or less (about 10 feet). Surface water is widely present in southwest Bangladesh because of omnipresent rivers and an extensive system of GOB build and maintained secondary (and sometimes tertiary) canals, though many of these are only full during the rainy summer season (aman), or aman and fall (robi) growing seasons.

While the AFPs were introduced primarily to encourage farmers to plant wheat and maize during the boro seasons, it was understood by the CSISA-MI project leadership that the largest use would likely be for rice. This would especially be true in the boro season, because rainfall in the aman season is usually sufficient so irrigation for rice is not required.

For rice, the purchasers of AFPs have been block managers[13], not LSPs. Small irrigated rice plots are organized into large, contiguous areas, or blocks, so that irrigation can be provided to the entire area from one common source, creating economies of scale and scope. Irrigation for these blocks is provided by a block manager on a fee for service basis. While similar to the LSP business model, the block manager model differs because even though the pumps are theoretically transportable, block managers prefer to situate their pumps in fixed installations.

In addition to boro rice, the other main use for pumps has been fish farming. While most small farmers in the region do have small fish ponds for their own use and to earn some extra cash, the fish farms that have bought AFPs are the large commercial ones called ghers. Most ghers have several pumps. Of the gher owners who participated in the GDs, the minimum was five pumps per owner. Gher owners do not provide pumping services to other farmers at all. There has been very limited use of AFPs for wheat and maize (see Table VIII). Thus the agronomic and economic benefits relevant for adoption are related to rice and fish farming.

Block managers have not changed the prices they charge to small rice farmers for pumping services, given that they have quasi-monopoly power over farmers in their block. Thus the economic benefits of AFPs have mostly accrued to block managers and gher owners. The major benefit for small rice farmers is that their fields are irrigated more quickly. The benefits of the AFPs over their predecessor LLPs are that AFPs:

- Require substantially lower diesel costs, around 40-50 percent less;
- Pump higher volumes of water per hour for the same diameter pump, around 50 percent more;
- Require less maintenance; and
- Do not need to be primed by pouring water through them during the cold winter months, which often involves someone getting into the water and requires two people to start the machine.

AFPs have significant economic advantages despite the fact that they cost a multiple of the LLPs that they replace. LLPs cost BDT 2-4,000 ($25-50), depending on the size, and last for several years. AFPs suggested market retail price (SMRP) is BDT 15,000 (US$192) for the 4 inch pumps that RFL imported from Thailand, and is likely to be BDT 18,000 ($230) for 6 inch pumps now being tested by RK Metal, a small agricultural machinery manufacturer based in Faridpur that sells primarily in southwest Bangladesh. Additionally, The Metal (Pvt.) Limited, a CSISA-MI partner, designed, domestically manufactured and sold a pump in 2015 made with improved metal and a larger diameter, for a retail price of BDT 25,000

[13] Several years ago the Bangladeshi authorities encouraged most irrigated rice farmers to reorganize themselves into contiguous units so that the flooding and pumping of water could be organized a mass or group scale, benefiting from economies of scale and scope. This is now the case in most of the region, where a large number of farmers will have contiguous small plots in one large area, usually many hectares. Block managers provide irrigation and pumping services to an area, called a block, and use one or more pumps to move water from secondary and tertiary canals to the block.

($320). Despite the higher initial capital investment, the savings on diesel fuel quickly make the AFPs much more profitable, especially as newer models of AFPs, both imported and those of Metal, will be made of a higher gauge metal (14 versus 16). The new pumps are expected to last several years, similar to LLPs. Additionally, LLPs require much more frequent maintenance, such as replacement of bearings, than AFPs, reducing some of the benefit of their longer duration.

Based on the finds from this study, adoption of AFPs did not require any change in good agricultural practices (GAPs), adoption of other innovations, or additional use of inputs. According to CSISA-MI and the review team's own interviews with gher owners and block managers, adopters already owned diesel engines; by and large the choice of pump diameter has been determined by the capacity of existing diesels. Farmers with smaller diesel engines have been requesting that CSISA-MI work with its PSPs to introduce a 3-inch diameter AFP that can be driven by their engines. That is currently being researched.

2. Power Tiller-Operated Seeder

PTOS (seeders) have four functions: tilling, land leveling, seeding, and fertilizer application. Prior to the introduction of seeders, the tilling function in Bangladesh was done by power tillers or by plows pulled with animal traction, and more recently rotovators. Seeding is currently done by hand broadcasting in SW Bangladesh. This is true even for some rice, e.g., farmers growing jute in the boro season broadcast rice into wet jute fields.[14] Fertilizer is also usually broadcast, with the exception of a small number of rice farmers using guthi (briquettes of compressed urea).[15] Of the models of PTOS being promoted, the BADC design uses an incline plate and can plant a greater variety of seeds, including maize, whereas the RFL import from China uses a fluted roller and is more limited. However, the RFL design has a fertilizer capacity that the BADC design does not have.

PTOS are attached to power tillers which provide the drive force. The availability of power tiller owners and services varies widely in SW Bangladesh. Until the analysis from the Bangladesh first machinery census becomes available (the data was collected in 2015 and was still being processed at the time of this writing), the only data available is based on that collected union-by-union by the resident SAAO. The power tiller coverage in several sample unions in the GD, based on interviews with five SAAOs in Jhenaidah, is presented in Table XI. As can be seen, the number of hectares and farmers per power tiller varies widely.

TABLE XI: AGRICULTURAL CHARACTERISTICS IN FIVE SELECTED UNIONS IN JHENAIDAH

Characteristic	Union 1	Union 2	Union 3	Union 4	Union 5
Number households	1600	2000	1555	1700	2150
Hectares	658	976	795	1008	961
% Landless	5-6%	4%	5%	4%	15%
Power tillers	125	112	165	125	125
Power threshers	25-30	5	11	12	5
HH per power tiller	12.8	17.9	9.4	13.6	17.2
HA per power tiller	5.3	8.7	4.8	8.1	7.7
Number of crop cycles	Mostly 3	Mostly 3	3 to 4	NA	NA

[14] Most rice planted in the prime aman season is transplanted by hand. While machine transplanting of rice has been introduced in northern Bangladesh, it has yet to gain a foothold in the southwest.

[15] Guthi are inserted at the intersection of four rice plants a few inches below the surface, either by hand, using a hand applicator, or with a hand-pushed rolling applicator. Guthi have been introduced with mixed success by the International Fertilizer Development Center, and their effectiveness is currently under assessment

Characteristic	Union 1	Union 2	Union 3	Union 4	Union 5
Principal non-rice crop	Onions	NA	Onions and jute (cash)	Wheat, onions, lentils	Onions, bananas
Price of labor/day	TH 350	TH250 (shorter day)	NA	TH400	TH250-300
PTOS purchased	0	1	3	4	6
Reapers purchased	0	1	1	2	0
AFPs purchased	0	0	0	2	0
Comments	Very poor union, most LSPs paid in share of crop	Buyer has more money than average	Better off union, 200 farmers received GOB mechanization training	Labor crisis	Many awareness sessions in this union

Like the AFP, the PTOS has a number of advantages. First, as a power tiller attachment, it has obvious appeal to the large installed base of power tiller owners. Second, while significantly more expensive than the AFP, the PTOS has a price point (BDT 40,000–55,000) that is still relatively affordable for many better off farmers, and depending on the size of the subsidy, PTOS LSPs can repay their loans in one to two seasons. Finally, it turns out that when farmers tried the PTOS, its greatest appeal was not the option to mechanize seeding and fertilizer, but to use it as a rotavator to produce a finer and deeper till which is particularly suitable for production of root crops such as onion and garlic.

Like the AFP, the PTOS was introduced to support wheat and maize cultivation on fallow land and improve productivity of existing production. As Tables IX and X show, there has been some adoption of PTOS for robi season wheat, and it has also been applied to jute in the boro season. For wheat, PTOS has the advantage of allowing farmers to adopt line sowing and even strip tillage, both of which are relatively new in SW Bangladesh. However, the majority of adoption has been for land preparation of onions and garlic, along with other vegetables. Thus adoption has been confined to those areas growing wheat, onions, and jute. As of this writing, farmers have begun to experiment with using the PTOS for land preparation and planting of pulses like mung beans, other vegetables, and sesame.

Unlike the farmers who use AFPs, those farmers buying PTOS have almost universally adopted the LSP model, with the exception of very large farms that use their power tiller full-time on their own land. This is not surprising given that most power tiller owners were already serving as LSPs. PTOS LSPs prioritize land preparation and seeding of their own land first, and then provide services to others.

As PTOS or rotovators are an attachment to the power tillers, like the AFPs and diesels, the PTOS is leveraging the existence of a large installed base of farmers who are already accustomed to mechanized tillage. However, the complementary practices of line sowing and simultaneous tilling, sowing, and fertilizing are much less familiar. The project found that some people loved the PTOS for its excellent tilling capacity and either never used the seeder box or removed it completely. Other people—especially if they were trained by CSISA-MI—liked the feature of tilling and sowing (unnecessary for garlic and onion, but better for cereals, mung bean, jute, etc.). Based on the findings of this study, the PTOS had several characteristics that facilitated scaling up.

- From a tilling perspective, the PTOS replaced an existing technology (power tillers). It prepares soil more quickly and at lower cost than a power tiller, because it requires fewer passes, and does not require waiting for a few days between tilling passes.
- The PTOS prepares soil with a finer and deeper till, allowing for better root growth and easier planting of crops that use bulbs. The finer till allows planters to plant more bulbs more quickly with less damage to their fingers and hands. In some areas where labor is particularly scarce,

labor refuses to plant onions and garlic unless the land has been prepared by a PTOS or rotavator.

- The PTOS allows for line sowing of seeds for cereals, and potentially strip tillage, which should generate higher yields as it facilitates weeding; gives individual plants more access to sun and air circulation; and decreases vulnerability to disease, especially fungus from excess rain or moisture, and from pests like rats.
- The PTOS decreases the need for hired labor during the land preparation and planting season, especially for activities like planting onion and garlic bulbs.
- The PTOS uses and leverages an existing investment (installed power tiller ownership).
- Adopting PTOS implies no change in farming practices for onions, garlic, or vegetables.
- The PTOS saves in labor and time required for land preparation and seeding/planting.
- The PTOS allows for planting at early times and longer growing seasons.
- If adopted with line sowing and strip tillage, PTOS increases cereal yields significantly.
- Farmers can potentially use the PTOS for 3 seasons (about 56 days per year), with application to a wide variety of cereals and horticulture crops.
- Farmers and LSPs can see a strong business case for the PTOS (see below). They often recoup their investment in a single season, at most two seasons, due to high rates of return.

The PTOS also had characteristics that made initial adoption and scaling more challenging:

- The PTOS has a higher price point than the AFP.
- Farmers and LSPs require a longer learning curve to operate and repair the PTOS.
- Differences in existing machinery may create a need for multiple versions of the PTOS. Two versions had to be imported to be compatible with the two most common types of power tillers and their different types of attachment connection structures.
- The PTOS is more complicated to operate than the AFP. The seed box settings must be adjusted for different sizes of seeds, which is labor intensive, so LSPs have tended to provide services to farmers all growing the same crop, or have discarded the seed box altogether.
- Sales and service are important for PTOS adoption. With many moving parts, a guaranty and warranty, access to quality after sales service, and especially spare parts for RFL's imported PTOS were an important consideration.
- The PTOS provides one function that is not relevant to the local context. The fertilizer box included on the initially imported machine is meant to use a composite fertilizer widely available in China, but not available in Bangladesh. The combination of fertilizers that Bangladeshi farmers prefer melts in the machine and clogs the PTOS fertilizer box. Very few farmers are using the fertilizer box.

3. Self-Propelled Reaper (SPR) and Power-Tiller Operated Reaper (PTOR)

Unlike the AFP and PTOS, reapers are replacing hand harvesting; there has been little successful effort to mechanize reaping to date.[16] Self-propelled reapers (SPRs) lack some of the advantages of the AFP and PTOS. Their greatest advantage is that they save labor, time, and costs, and that they allow boro crops (rice, jute) to be harvested in a timely way before the monsoon rains arrive. Their biggest disadvantages are that they are only suitable for cereals, they are quite expensive (BDT 150,000-180,000 or US$1,900-2300) and require financing for most farmers to purchase, and they are only useful for

[16] There are large numbers of mechanical threshers already in place, but the majority are hand-powered vs. machine driven. Combine harvesters exist, but are infrequent; sometimes owners bring them down from the north after they have finished working there, or large scale LSPs bring them over from India. BADC has a few on its research stations which it uses for demonstrations and lends out.

approximately 20 days out the year. However, even though reapers imply significant savings in terms of cost and time, their success is heavily linked to the availability of mechanized threshing services. In places where mechanical threshing services were not available, local labor recruited to do threshing would in some instances refuse unless they were hired for reaping as well, negating the benefit of the availability of a reaper LSP. Given that wheat and maize are much less widely grown in the southwest than in the north of Bangladesh, reapers in the southwest are in many areas only currently able to be used for one crop.

The project initially introduced the SPR, however the high cost has led to much slower adoption despite subsidies, though the recent introduction of GOB price subsidies appears to have helped. Recently CSISA-MI and its corporate partner, Janata Engineering, introduced a power-tiller operated reaper (PTOR), which is much less expensive and potentially more promising. The PTOR, which had successful field trials conducted by CSISA-MI from November to December 2015, was being test marketed to farmers for the boro harvest from April to June 2016. Its principal disadvantage is that it appears to require more time to master turning it at the end of rows. After observing Janata Engineering's success with the first batch of PTORs in Year 3, Alim Industries and Real Power have entered the market. 168 PTORs have been imported at the start of Year 4.

4. Bed Planters

Bed planters form fields into alternating beds and furrows for more efficient dry season irrigation. They are particularly beneficial for corn and maize by requiring fewer seeds, less land preparation, and lower sowing costs while increasing yields. They also decrease the risk of a crops being contaminated with arsenic by improving drainage.

In the SW Bangladesh context they had two major problems. First, they were large, heavy, expensive, and difficult to maneuver.[17] Second, planting in raised beds is not commonly practiced in SW Bangladesh. As noted above, in general the growth of wheat and maize is currently quite limited, and even where farmers grow these crops, there is no tradition of using raised beds for wheat, maize, or vegetables. Therefore, adoption would have required a substantial change in GAPs. Ultimately the project decided to drop the bed planter.

IV. SCALING UP PATTERNS AND RATES OF ADOPTION OVER TIME, SPACE, AND DEMOGRAPHICS

It took two years for CSISA-MI to accelerate sales and adoption of new agricultural machinery and services by LSPs and farmers (See Tables VIII-X). This data does not included use by farmers through CIMMYT demonstration efforts,[18] only by owners (LSPs themselves) and their client farmers. However, as evidenced by Table VIII above, the initial introduction and adoption of the technologies contained a number of surprises. The crops and purposes for which the machines are actually being used ended up being rather different than what was intended by the project, and in some cases required modifications to the design and manufacture of the machinery to be appropriate for the SW Bangladesh market. AFPs were adopted largely for rice and fish, rather than for wheat or maize. Additionally, the AFP has been

[17] The average size of a Bangladeshi male is 52.9 kilos (120 lbs) with a standard deviation of ± 8.95 kg or 19.6 lbs. For height in the average is 160.6 cm or 5 foot 3 inches, with a standard deviation of ± 6.2 cm or 2.4". This was based on a sample with average age of 31 years old. Source: Tania Sultana , Md. Nazmul Karim, Tahmeed Ahmed, and Md. Iqbal Hossain. "Assessment of Under Nutrition of Bangladeshi Adults Using Anthropometry: Can Body Mass Index Be Replaced by MidUpper-Arm-Circumference?" PLOS ONE | DOI:10.1371/journal.pone.0121456 April 14, 2015. URL: http://journals.plos.org/plosone/article/asset?id=10.1371%2Fjournal.pone.0121456.PDF.

[18] As part of CSISA-MI's efforts to increase awareness and adoption of the machinery, CIMMYT teams both conducted demonstrations on farmers' fields and loaned machinery to farmers to try.

redesigned to be stronger, more durable, and longer lasting to meet conditions in SW Bangladesh. The other machine that has had quite a bit of success is the PTOS, which is being largely used by horticulture farmers, particularly for crops that require a fine till such as onion and garlic. However, the fertilizer boxes proved not to be compatible with farmers' preferred type of fertilizer, and the seeders were of limited utility and attractiveness to farmers. So in many cases LSPs have sealed off the fertilizer from the PTOS and simply use it as a rotovator. The reapers had low initial uptake in the FTF ZOI, though initial use was largely as intended, for rice and wheat. However, reaper sales have improved due in part to government subsidies and the introduction of zero-percentage long-term financing.

CSISA-MI is in its third year and scaling is still in progress. However, the initial results show promise. According to internal data from CSISA-MI and interviews for this study, the majority of early LSP adopters were relatively young (20-50), male, married, and had prior experience operating agricultural machinery. One third had education up to Class VII, one third had education up to Class V, and 12 percent were illiterate. They had an average household income of BDT 19,518 ($247.50 monthly or $2,970 annually) in 2012, which went up to BDT 26,987 ($342.20 monthly or $4,106.40 annually) in 2015 (compared with average per capita GDP of $1,086.80 for 2011-2016[19]). The primary occupation of 76 percent of the LSPs is agriculture, followed by 6 percent in fishing. Only 5 percent identified "LSP" as their primary occupation. In 2012, LSPs identified 21 percent of their income as coming from agro machinery services. In 2015, despite the rise in overall household income, the percentage of income attributed to agro machinery services remained relatively proportionate, at 26 percent.

Scaling up has been largely extensive, taking the form of additional LSPs buying machinery, rather than existing LSPs buying more machines or using them more. While a few LSPs have bought either a different machine or an extra of a machine they already had, the majority only own one machine. This is due to both socioeconomic constraints and constraints of time and interest (many others have multiple businesses and are not interested in investing). While most LSPs hire an additional operator to alternate with during a day in the busy times of the year, almost all LSPs are reluctant to hire operators without themselves being present onsite. This appears to be largely due to concerns over reputation effects, as most service users are friends and neighbors of the LSP. The exceptions are gher owners who often purchase several pumps and use them in their own ponds. According to CSISA-MI's own research, LSPs cited four reasons for purchasing machinery. The LSPs:

1. Were financially motivated to provide LSP services;
2. Intended to use the machinery on their own property and crops, without selling services;
3. Wanted the respect from their community that would be generated by helping other community members; and/or
4. Wanted to be the first to own something new.

Direct machinery sales from the PSPs indicate that those people who bought during the first two years of the project did so because of awareness and encouragement fostered by CSISA-MI. However, ongoing data collection by CSISA-MI and anecdotal evidence strongly suggest that trend is changing, and the market for agricultural machinery in the FTF zone is beginning to grow on its own. For example, in Faridpur in Year 2, iDE field staff knew nearly all of the people who bought PTOS, because of their attendance at project events. By Year 3, iDE field staff indicated that they knew fewer than 50 percent of the customers. Although the Year 3 data is not fully collected and aggregated at the time of this writing, there is anecdotal and survey evidence that indicates adoption and awareness based on word-of-mouth were increasingly common throughout the FTF zone by Year 3, which is a good indicator of spontaneous scaling.

[19] Source: World Bank, World Development Indicators, GDP per Capita in Current US$, http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

In terms of selling LSP services, family and community relationships were extremely important. Relatives, friends, and neighbors were a primary source of initial customers. As there is currently excess demand for services, people with relationships tended to be more successful. Thus sometimes new LSPs were people who could not find existing services. Many LSPs decided to buy a machine after seeing a friend or relative do so, and the same was true for farmers in buying services. Mechanics played an important role in encouraging LSPs to buy machines. The influence of SAAOs was less important, but varied widely depending on the credibility of the individual SAAO. SAAOs who were older or had demonstrated effectiveness in increasing productivity or reducing costs were important.

It appears that in many cases adoption began with highly profitable cash crops like onions or fish, and/or where mechanization already existed (e.g., presence of power tillers for PTOS or LLPs for AFPs). However, in the first year CSISA-MI did not know what demographic groups or locations had the highest potential to be early adopters, so the project began working in areas that were logistically feasible. As a result, the spatial patterns and sequence of adoption were driven as much by project constraints as by market factors. The project selected initial areas to work in based on a combination of:

- Access to supply chains and sales channels,
- Access to CIMMYT and iDE hub and satellite offices, and
- Agronomic appropriateness of the machinery (e.g., fallow lands for PTOS, wheat and maize for reaper, surface water for AFP).

Another significant influence on location was the preferences of the PSPs who were and continue to be risk averse. PSPs initially targeted areas (and dealers) in places where they had had previous success in selling machinery. As the project proceeded with work in these areas and began collecting data that suggested promising trends, they have been able to target project activities toward regions and population groups with greater efficiency (Annex D provides spatial adoption patterns of each machine over the project duration). This included helping PSPs to identify and recruit new dealers in high potential areas where no dealers were located.

Many of the original project's estimates of potential market size for the machines were made using arms-length agro-ecological data (see Table XVI). These had to be modified once local contextual nuances were understood. The project estimated the market size for the reaper in the thousands, but this was eventually amended to take into account the contextual data that emerged from the project's field team, specifically that many of the areas originally considered feasible had water that was too high for the reaper to function properly. In addition, another challenge was with cultural practices relating to harvesting. [20] This illustrates that agronomical research is necessary but not sufficient in determining areas for technology introduction. According to iDE field managers, in hindsight, if they had economic and social data on all areas, they probably would not have selected some for commercialization. However, having learned from this experience, iDE conducted a market size study in Year 3 (see Table XVI).

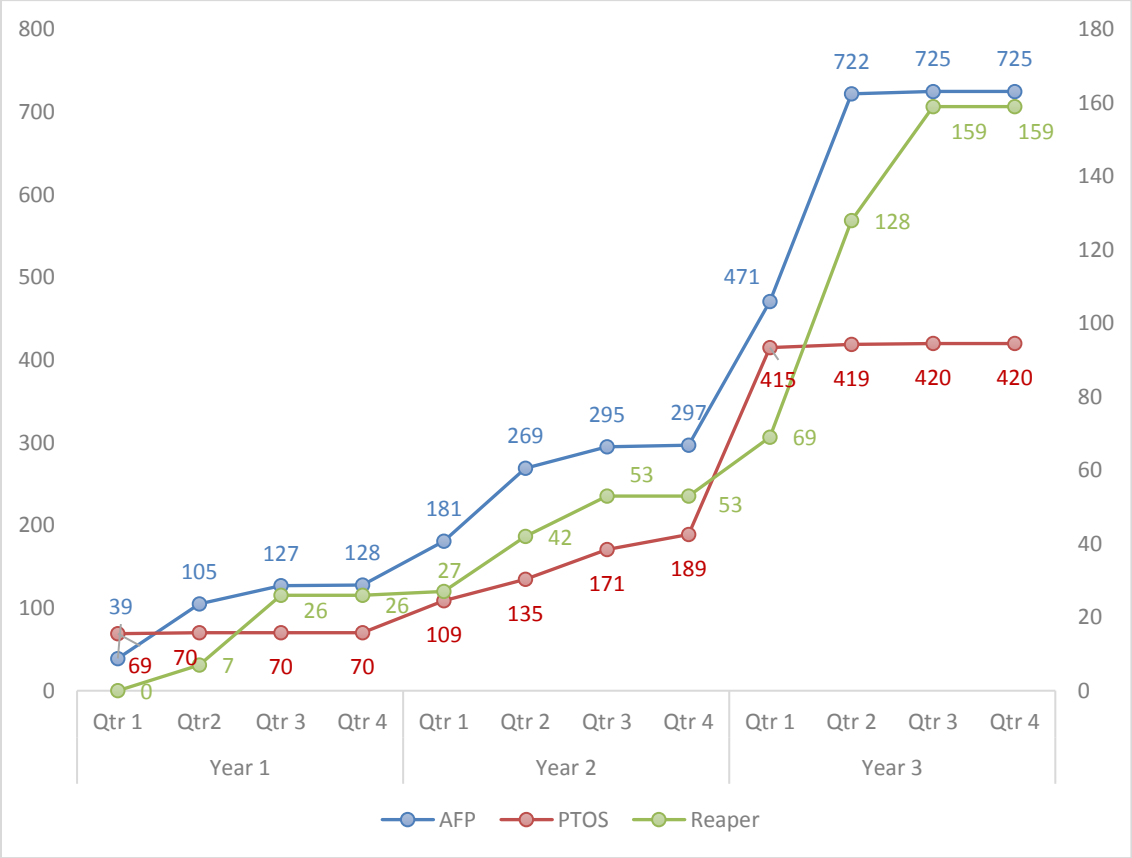
One of the major lessons about adoption patterns from CSISA-MI is the importance of understanding how targeted communities perceive and respond to risks. Many communities appeared to have the appropriate crops, agro-ecological zones, resources, and demographic characteristics, yet still were late

[20] For example, a community in the Jessore/Jhenaidah area is an ideal candidate for reaper adoption. However, they are finding it difficult to adopt the reaper because they have a long-standing practice of cutting rice at the lowest level possible in a hand bundle, or *bichali*, which the machine cannot do. They use the bundled rice stalks for animal feed and roof thatching. Similarly, a wheat-intensive area called Bhola is resistant to adopting the reaper because of a local practice where they just cut and thresh the tips; then later they come back through and cut the stalks for cattle feed.

adopters because of risk aversion. This is particularly true of communities that have experienced or are prone to natural disasters.

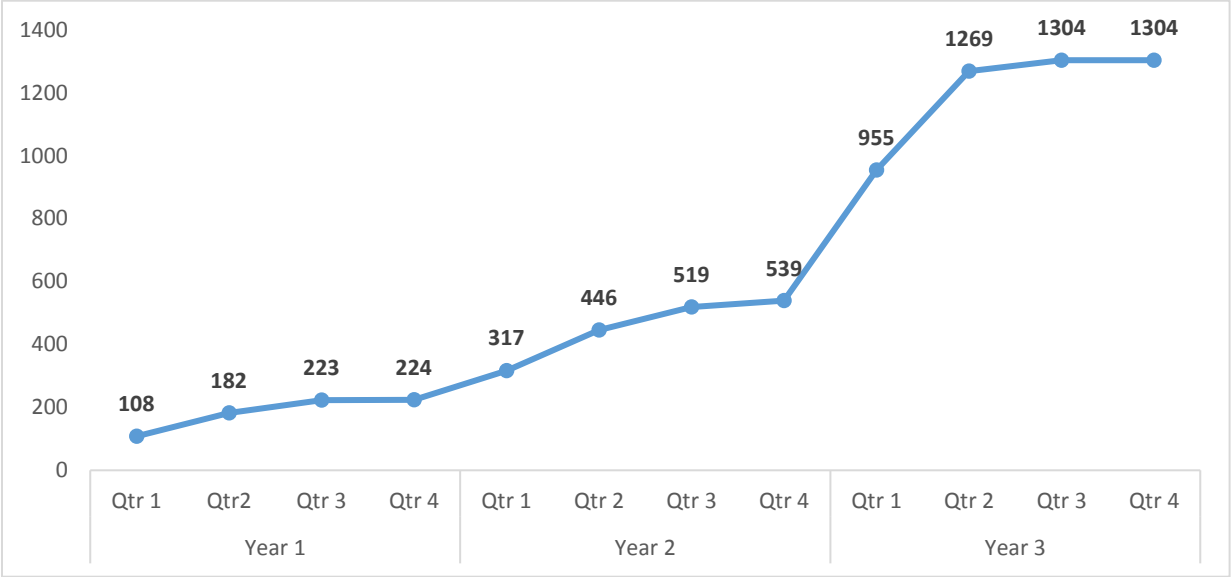
As can be seen in Figures 2-3, by the beginning of the third year there appears to be an acceleration in the number of machines sold and number of LSPs buying machines. This was true for all three machines. This in part reflects the CSISA-MI strategy of narrowing its efforts to locations with high uptake potential. Whether this indicates the reaching of the tipping point in the S curve remains to be seen.

FIGURE 2: CUMULATIVE SALES BY MACHINE



Source: CSISA-MI

FIGURE 3: CUMULATIVE SALES BY NUMBER OF LSPs



Source: CSISA-MI

The more granular data in Figure 3 shows that buying is quite seasonal and appears to occur before the beginning of the primary time of year when each machine would be used.

In addition to the surprises about the uses of the machinery and improving its quality and utility, the business models actually used by farmers showed several important lessons. First, AFPs have not been adopted by LSPs who provide services for their neighbors, at least not on a mobile basis. Almost all pumps have been purchased by gher owners or block managers who keep them in one place, or move them very short distances and use them for their own purposes. Secondly, there has been a fairly high variance in the business skills of LSPs who do provide services using PTOSs or reapers. Because of this, the project has engaged in significant support in business development training. Finally, and on a similar note, the project management noticed that people who took large loans (for the reaper) did not necessarily know how to manage the debt well, especially since the income from reapers is so seasonal. In response they added a financial management training component, which was not a part of the original plan.

V. THE BUSINESS CASE FOR LSPs AND FARMERS

The qualitative business case for farmers and LSPs was discussed in the previous section. Before looking at the business case for LSPs, it is helpful to look at the crop budgets for some of the most important crops in SW Bangladesh – aman and boro rice, wheat, onions, and jute. Summaries of these are shown in Table XII. (Figures were not easily available for fish farming or for the labor costs of different activities for the crops below, especially land preparation, planting, and harvesting.) As can be seen below, onions far and away require the highest investment but have an even greater return, both in absolute and relative terms. As CSISA-MI was to learn, the importance of this cash crop and the large returns and resources required made onion growers an ideal adopter of the one machine that was relevant for them, PTOS. This was especially the case as land preparation and labor accounted for nearly half of production costs, a proportion exceed only by jute. By contrast, the potential for labor saving in wheat and rice is much smaller, especially aman and boro rice. However, based on the findings in this study, because the initial machinery selection was made on an agronomic and not economic/financial basis, these factors were not taken into account.

TABLE XII. CROP BUDGETS FOR FIVE KEY CROPS IN SW BANGLADESH (IN TAKA)

	Aman Rice	Boro Rice	Wheat *	Onions*	Jute*
Total variable cost	**51,245**	**72,536**	**59,281**	**149,663**	**89,430**
of which					
Land preparation	7,905	5,928	7,500	10,000	10,000
Hired labor	7,500	14,820	13,750	54,000	57,000
as a percent of TVC					
Land preparation	15.4%	8.2%	12.7%	6.7%	11.2%
Hired labor	14.6%	20.4%	23.2%	36.1%	63.7%
Gross returns	**77,000**	**82,827**	**71,875**	**280,000**	**142,875**
of which					
Grain, fruit, vegetables (value)	72,000	78,217	70,000	280,000	121,875
Other (straw, plant material)	5,000	4,611	1,875		21,000
Note: grain, gruit, vegetables (quantity in KG)	4,500	6,257	3,500		3,250
Net returns	**25,755**	**10,291**	**12,594**	**130,337**	**53,445**
Rate of return on TVS	50.3%	14.2%	21.2%	87.1%	59.8%

Source: CSISA-MI

* Wheat, Jute and Onions Labor includes value of Family Labor as well

An indication of the business case for LSPs (and to some extent farmers) for different crops and for each of the machines is presented in Tables XIII to XV below. (Note that for all three machines, the full retail price of the machine is used in the calculation, even though to date the seeder and AFP have benefitted from significant price subsidies of around 30 percent. This has recently been extended to the reaper by the GOB, though only for a fixed number of reapers.) For both wheat and onions, using the seeder cuts the costs of tilling a bigha[21] by more than half (there is little savings for jute, not shown). Almost all of these savings have been passed on to farmers. These tangible benefits do not include the labor savings in planting nor the time savings in labor preparation and planting, which is particularly important in the case of onions.

The lower cost to farmers translates into higher profit rates for LSPs. There are higher overall profits because of the lower costs of the seeder and the fact that seeders can be used for more bigha per day and more days during the year. As a result, breakeven calculations show that the typical breakeven period for LSPs with PTOS is two-thirds of a year, versus nearly 2.7 years for power tillers. (All of these calculations assume that LSPs already own a PTOS, i.e., are not buying both a PTOS and Power Tiller at the same time). This is comparable to what LSPs who bought seeders reported in interviews, i.e., the repayment period for a PTOS ranged from a half-season to a full calendar year. Of course this analysis only compares the two tilling functions, and does not attempt to take into account the fact that a seeder can only be used with a power tiller.

The question of the business model for the reaper must be considered from the perspective of both the LSP and the farmer. For farmers, the costs of using a reaper are half of those for manual labor, representing a 50 percent cost savings for farmers, again not including the savings in terms of the time reaping takes and waiting for a labor crew to come through. Assuming that reapers can be used for aman rice, wheat in the robi season, and boro rice in the boro season – and assuming that the LSP does not take a loan and is successful in securing sufficient demand for his services – the repayment period for a reaper is 1.8 years at the price of BDT 170,000. If the current price for reapers drops by 30

[21] A bigha is equivalent to one-third of an acre, or 14,400 square ft or 1,337.8 square meters.

percent (the current level of the GOB subsidy introduced in late 2015), the repayment period drops to 1.2 years (again, assuming high demand for services).

However, not all LSPs find high demand for their services, particularly as the reaper service is a new one in the market. Two years is what LSPs shared in GDs, and this was likely without reaping much rice or jute. The most recent statistics from CSISA-MI show that out of 323 total hectares worked by reapers, only 60.7 ha were in rice (i.e., 10 percent). The project team, based on research this past year, discovered that the breakeven point increases considerably when LSPs take high interest loans to buy the machine and when they are unable to find sufficient demand, or when a disease such as wheat blast harms a significant portion of a key crop. For this reason, the project is working with its private sector partners to explore a much cheaper power tiller operated reaper attachment, which retails at about a third of the price of the self-propelled reaper. Based on pilots with this technology last year, the team calculates that even when demand is low, an LSP who uses the reaper attachment can break even at 1.6 years.

The business model for AFPs (as opposed to LLPs) is based on 4-inch, 20-foot pump used by a block manager to irrigate rice (it does not include the price of a diesel engine to drive the pump). The retail price of the AFP is nearly three times that of the LLP. This is offset by a savings of 40 percent on annual fuel costs, as well as labor savings. The repayment period for an AFP is 0.46 years (as opposed to 0.21 for the LLP), and this is assuming that a block manager uses an AFP to irrigate a 50 percent larger area given the greater capacity of the AFP.[22] AFPs are more profitable than LLPs on either a per bigha or annual basis, as can be seen in Table XV. This even more true over their lifespan. Even though AFPs only last one-third to one-half as long, i.e., 3 to 5 years versus 10 years, so you would have to buy 3 over a 10-year period, they are 64 percent more profitable than LLPs. Furthermore, AFPs are much easier to use (all users mentioned the advantages during the GDs of not having to prime them in the winter), and faster; they have a higher pumping capacity in terms of volume of water per hour. For many users, time and convenience is money. However, it is important to recall that there is to date no evidence that block managers have passed any of these savings or increased profits onto rice farmers; they charge the same for irrigating their fields for either pump. Farmers do report a major benefit, which is more prompt irrigation, allowing for earlier planting and a longer growing season, and a greater willingness by block managers to provide supplemental irrigation over the season, if needed.

[22] Assuming that the area of the block (under irrigated boro rice cultivation) does not change, then the repayment period for an AFP extends to 0.79 years.

TABLE XIII: BUSINESS MODEL FOR PTOS (VS. POWER TILLER) IN TAKA

PTOS vs Power Tiller - Business Model			Wheat		Onion		Annual Average (includes Jute)	
CATEGORY		ITEM	PTOS	Power Tiller	PTOS	Power Tiller	PTOS	Power Tiller
A	Initial Investment (does not include cost of Power Tillers for PTOS)		BDT 55,000	BDT 110,000	BDT 55,000	BDT 110,000	BDT 55,000	BDT 110,000
	Lifespan (years)		10	30	10	30	10	30
B	Operation Costs	Fuel	BDT 140	BDT 560	BDT 280	BDT 840		
	(Per Bigha)	Operator's Salary	Owner operated	Owner operated	Owner operated	Owner operated		
		Maintenance	BDT 40	BDT 20	BDT 40	BDT 20		
		Total Operations Costs per Bigha	BDT 80	BDT 580	BDT 320	BDT 860		
C	Profit/ Loss per Bigha							
		Service Charges per Bigha	BDT 500	BDT 1,200	BDT 1,000	BDT 1,800		
		Gross Profit per Bigha	BDT 320	BDT 465	BDT 680	BDT 940		
D	Break Even Analysis							
	i	Productive Seasons per Year	1	1	1	1		
	ii	Average Number of Operation Days per Season	16	16	20	10		
	iii	Optimal Bigha Coverage per Day	6	2	3	1		
		Operational Efficacy (Bigha/Year)	96	32	60	13		
		Annual Revenue	BDT 48,000	BDT 38,400	BDT 60,000	BDT 24,000	BDT 138,000	BDT 86,400
		Annual Cost	BDT 17,280	BDT 18,560	BDT 19,200	BDT 11,467	BDT 47,280	BDT 42,027
		Annual Depreciation					BDT 4,950	BDT 3,300
		Profit	BDT 30,720	BDT 19,840	BDT 40,800	BDT 12,533	BDT 82,470	BDT 41,073
		Typical Break Even Point (Years)	1.79 (5.4 with purchase of Power Tiller)	5.54	1.35 (4.0 with purchase of Power Tiller)	8.78	0.65 (2.0 with purchase of Power Tiller)	2.68

Source: CSISA-MI

TABLE XIV: BUSINESS MODEL FOR REAPER (VS. LABOR), FOR AN LSP

			Wheat		Aman Rice		Boro Rice		Annual Average	
			SPR	Labor	SPR	Labor	SPR	Labor	SPR	Labor
A	**Initial Investment**	**MRP = BDT 170,000**	**BDT 170,000**	**BDT -**	**BDT 170,000**	**BDT -**	**BDT 170,000**	**BDT -**	**BDT 170,000**	**BDT -**
B	**Operation Costs**	Fuel	BDT 45	BDT -	BDT 45	BDT -	BDT 45	BDT -		
	(Per Bigha)	Transporter and Operator's Salary	BDT 42	BDT -	BDT 50	BDT -	BDT 63	BDT -		
		Maintenance	BDT 10	BDT -	BDT 10	BDT -	BDT 15	BDT -		
		Total Operations Costs per Bigha	**BDT 97**	**BDT -**	**BDT 105**	**BDT -**	**BDT 123**	**BDT -**		
C	**Profit/ Loss**									
	(Per Bigha)	**Service Charges per Bigha**	**BDT 500**	**BDT 1,000**	**BDT 500**	**BDT 1,000**	**BDT 500**	**BDT 1,000**		
		Gross Profit per Bigha	**BDT 403**	**BDT 1,000**	**BDT 395**	**BDT 1,000**	**BDT 378**	**BDT 1,000**		
D	**Break Even Analysis**									
		Productive Seasons per Year	1	1	1	1	1	1		
		Average Number of Operation Days per Season	10	15	8	6	6	8		
		Optimal Bigha Coverage per Day	6	1	5	1	4	1		
		Operational Efficacy of Machine (Bigha/Year)	60	15	40	6	24	8		
		Annual Cost	**BDT 5,800**	**BDT -**	**BDT 4,200**	**BDT -**	**BDT 2,940**	**BDT -**	**BDT 12,940**	**BDT -**
		Annual Depreciation							**BDT 15,300**	**BDT -**

		Annual Interest for 2 Years							**BDT 12,500**	**BDT -**
		Annual Revenue	**BDT 30,000**	**BDT 15,000**	**BDT 20,000**	**BDT 6,000**	**BDT 12,000**	**BDT 8,000**	**BDT 62,000**	**BDT 14,000**
		Annual Profit	**BDT 24,200**	**BDT 15,000**	**BDT 15,800**	**BDT 6,000**	**BDT 9,060**	**BDT 8,000**	**BDT 21,260**	**BDT 14,000**
		Typical Break Even Point (Years)	**7.02**	**0.00**	**10.76**	**0.00**	**18.76**	**0.00**	**8.00**	**-**
E	**Life Cycle Analysis**								**Over 10 Years (SPR Lifespan)**	
		Cost							BDT 307,400	
		Revenue							BDT 620,000	
		Profit							BDT 312,600	

Source: CSISA-MI

TABLE XV: BUSINESS MODEL FOR AXIAL FLOW PUMP VERSUS LOW-LIFT PUMP, IN TAKA***

Category		Item	AFP	LLP
A	**Initial Investment**	**4" x 20' AFP Purchase - Block Manager**	**BDT 17,700**	**BDT 6,000**
B	**Operation Costs**	Fuel	350	490
	(Per Bigha block per Season)	Labor	35	75
		Pump and Engine Maintenance	10	10
		Pump Repair and Spares	15	10
		Total Operations Costs per Bigha	**410**	**585**
C	**Profit/ Loss per Bigha Gher**	Service Charges per Bigha	1,300	1,300
		Gross Profit (per Bigha)	**890**	**715**
D	**Break Even Analysis**	Productive seasons per year (Block)	1	1
		Number of operations day per season (average)	60	60
		Optimal Bigha coverage per day	0.75	0.5
		Operational Efficacy of machine (Bigha/year)	45	30
		Annual Revenue	**58,500**	**39,000**
		Annual Income	**18,450**	**17,550**
		Typical Break Even Point (Years)	**0.46**	**0.21**
E	**Ten Year Returns**	Ten Year Revenues	**382,500**	**207,000**
		Ten Year Costs (3 AFPs vs. 1 LLP)	**53,100**	**6,000**
		Ten Year Net Profits	**329,400**	**201,000**

Source: CSISA-MI. Calculations are for boro rice irrigation by block managers, and do not apply to fish ponds or ghers.

VI. POTENTIAL MARKET SIZE AND IMPACT

The potential market size varies by machine. As noted above, AFPs are only useful in places where lifting heights are under three meters, which is usually only in the southwest. Unlike AFPs, both PTOSs and reapers have a potentially national market. The PSPs are all approaching the PTOS and reaper with a national strategy, though the efforts of the CSISA-MI project have been concentrated in the FTF ZOI. Estimating the demand for PTOS is difficult, because there are potentially three kinds of seeders: rotavators only, rotavators with a seed box, and rotavators with a seed and fertilizer box. These vary significantly in cost, and in the crops to which they can be applied. The onion, garlic, and other fine-till crops the PTOS is primarily being used for are exclusively commercial crops, implying that the potential early adopters are better-off, have cash resources and more of a commercial/entrepreneurial mentality. Estimating the demand for reapers is also difficult, because of the variation in price and use for the SPRs and the PTOR. Private sector partner ACI, one of the largest agricultural machinery distributors in Bangladesh, estimates potential market size based on the shortage of labor available for harvesting, which its analysts believe to be about 35 percent. Translating this into the number of reapers needed, they arrive at a figure of approximately 40,000 reapers in Bangladesh.

CSISA-MI has done its own estimates of the potential market size for each of the three machines for the FTF Zone of Influence in SW Bangladesh. These are presented in Table XVI below, along with potential private sector investment, and range from 15-18,000 (Annex D provides the market size calculation method). Clearly the upside potential is huge.

TABLE XVI: POTENTIAL MARKET SIZE, FTF ZOI, BANGLADESH

FTF Districts	AFP Market Size Estimate	AFP - Potential Private Sector Investment at MRP ($)	PTOS Market Size Estimate	PTOS - Potential Private Sector Investment at MRP ($)	Reaper Market Size Estimate	SPR - Potential Private Sector Investment at MRP ($)	PTOR - Potential Private Sector Investment at MRP ($)
Bagerhat	1391	$315,731	79	$55,802	715	$1,557,776	$504166
Barguna	13	$3,004	137	$96,768	618	$1,347,319	$435769
Barisal	3298	$748,502	265	$187,053	545	$1,187,127	$384294
Bhola	1948	$442,082	762	$536,978	2649	$5,774,452	$1,867,885
Chuadanga	18	$4,191	1029	$725,618	290	$631,649	$204,487
Faridpur	0	$0	2433	$1,715,862	1339	$2,918,573	$944,167
Gopalganj	1788	$405,780	876	$617,557	1511	$3,293,721	$1,065,449
Jessore	820	$186,120	1530	$1,078,771	1585	$3,453,998	$1,117,628
Jhalokati	463	$105,077	20	$14,257	164	$357,535	$115,641
Jhenaidah	122	$27,591	1222	$861,659	1051	$2,290,850	$741,090
Khulna	596	$135,356	131	$92,388	516	$1,124,277	$363,846
Madaripur	828	$187,932	1173	$827,181	725	$1,579,367	$511,218
Magura	157	$35,618	2129	$1,501,266	522	$1,138,771	$368,077
Meherpur	0	$0	1430	$1,008,407	582	$1,267,378	$410,385
Narail	693	$157,275	409	$288,662	941	$2,050,330	$663,526
Patuakhali	1038	$235,553	152	$107,466	2079	$4,530,203	$1,465,962
Pirojpur	755	$171,409	44	$31,323	116	$252,610	$81,795
Rajbari	0	$0	1899	$1,339,241	513	$1,118,560	$361,731
Satkhira	708	$160,579	497	$350,638	1598	$3,483,150	$1,126,795
Shariatpur	541	$122,777	1164	$820,793	133	$288,924	$93,782
Total	**15179**	**$3,444,579**	**17384**	**$12,257,691**	**18191**	**$39,646,572**	**$12,827,692**

The exchange rate used is $1 = BDT 78. Source: CSISA-MI

In other case studies potential market size has been a critical issue, potentially because either the potential size was too small for suppliers to see it as profitable, or because changes in productivity would adversely affect output prices. This is less so in the case of agricultural machinery in SW Bangladesh. Large national machinery companies were interested in partnering with CSISA-MI both because of its technical expertise and also because they could also sell machines in the rest of Bangladesh without CSISA-MI support.

The effect on output prices is also less relevant. First, the major expected impact of adoption of these innovations is on cost rather than productivity. AFPs lower fuel costs; PTOS require fewer passes on the field, thereby saving time and money; and the amount of labor required by a reaper is significantly cheaper than is required to harvest by hand. These innovations do have a potential impact on productivity and production because of their effect on time and timing. AFPs allow boro rice farmers to plant earlier, increasing the length of the season and yields. In the face of labor shortages, seeders[23] and reapers will allow for planting and harvesting at the right time, presumably improving yields and lowering the risk of damage and losses from adverse weather events. In the longer run, if all the different types of mechanization have a significant cumulative impact on the length of the crop season, it may allow more farmers to plant an additional crop or even two per year. However, it will take a while for these productivity effects to be significant, and even so, SW Bangladesh is a relatively small share of national production in most crops. However, if scaling spreads to the rest of Bangladesh, there may be some effects on output prices, but this is several years down the road. Finally, prices for most of the relevant crops—such as wheat, rice, and onions—are largely set in regional markets, especially given the weight of India in South Asia.

VII. SCALING UP STRATEGY AND ACTIVITIES

Implementation and Adaptive Management Approach: Sales Strategy, Activities, and Targeting

Machines are primarily sold between November and April of each crop year, because this is the beginning of the robi season until the end of the boro season; these are the two seasons when the AFP, PTOS, and reaper have the most utility. The first season of the project was 2013-14. Sales were both well below initial targets and to farmers with very different crops than had been envisioned in the initial proposal. For example, only 134 AFPs were sold of the 1,200 AFPs imported by RFL, and none of these were used to support wheat or maize cultivation. Similarly, only 8 percent of farmers who used PTOS services used them for wheat or maize, whereas nearly half used them for onions and garlic, an unintended consequence. Immediate challenges were political unrest, adverse weather, and a very short start-up time for the project, which began in September 2013; there was so little time to negotiate agreements with the private sector and for the latter to order machines (a two-month lag to delivery) that key months of the selling season were missed. Longer-term issues were the length of time required to build effective private sector partnerships; the failure of some technologies to function as envisioned when introduced to an open market; and the length of time required to identify, target, and secure sufficient numbers of early adopters.

Once the first year results were in, it became apparent that hitting the targets originally envisioned would be impossible both overall and in encouraging maize and wheat production in fallow land in particular. Coincidentally, at the behest of USAID/BFS, an external scaling consultant[24] was in Bangladesh

[23] PTOS also increase productivity because mechanized line sowing – as opposed to broadcasting – saves seed and increases productivity.

[24] For full disclosure, that consultant is also the principal author of this paper. In interviews with both CSISA-MI and USAID Mission staff, both insisted that the consultant's intervention was critical to the strategic pivot that occurred.

to assist the USAID Mission in integrating scaling up into the Mission's FTF portfolio. The consultant visited the CSISA-MI project and made several recommendations to the project that facilitated a change in strategy. These were:

1. Speak to USAID about the unrealistic project targets to see what could be done to align them with more of an S-curve approach, i.e., focusing on creating the foundations for scaling up in terms of a critical mass of adopters and of a viable supply chain and marketing driven by commercial actors once demand accelerated;
2. Revise the list of machinery being promoted to include only those machines that were of real interest to the market;
3. Identify the characteristics of early adopters and locations and target them, even if they were not cereal farmers (e.g., onion farmers using the PTOS); and
4. Revise the project staffing strategy by hiring a professional and experienced project manager to be the chief of party (COP), allowing the existing project head, an excellent CIMMYT scientist, to focus on his areas of comparative advantage, research.

CIMMYT spoke to the USAID Bangladesh Mission and received permission to do all of the above. In interviews, the USAID Mission staff involved acknowledged that several aspects of this were unusual and facilitated by particular circumstances. First, they were willing to allow for low numerical targets in the early years because they had several other projects on line that would produce the large numbers that they felt they had to produce to satisfy USAID Washington. Second, they were able to change targets and strategies easily because it was a grant, not a contract or even a cooperative agreement. Third, they were willing to pursue what appeared to be a high-risk experimental approach—following market signals and being demand driven instead of pushing supply through demonstrations—again because they were pursuing the more traditional approach with other projects in the FTF portfolio.

The strategic pivot approved by the Mission was largely implemented. A new COP was hired and brought in within 6 months. The project pursued a two-track approach, one focused on maize and wheat (supply-push approach) and the other on selling machines and services based on farmers' felt needs (demand-pull approach). The two-track approach meant that CIMMYT's team and iDE's team were promoting the machinery in different ways, in largely different areas. The conflict in strategies can be attributed in hindsight to a variety of factors, perhaps most importantly (i) the Consortium of International Agricultural Research Centers (CGIAR) institution's focus on research and theoretical implementation and (ii) the market development firms' focus on market-driven strategy and private sector actor autonomy, which were both not applicable to the project design. [25]

From that point on, adaptive management was the operating principle of CSISA-MI, at least in the iDE half of the project and increasingly with CIMMYT as well.[26] The leadership of CSISA-MI realized that there were ongoing obstacles to adaptive management in practice. There were cultural challenges with local Bangladeshi staff. To address this, the DPM championed a cultural shift toward the team working together to create innovative solutions rather than implementing handed down directives. As discussed below, iDE accelerated the development of an additional M&E system, on top of that required to track FTF indicators, that would be used to collect market information and results in near real-time, and use this information to adjust marketing, sales activities, and targeting. This system, called Monitoring and Results Measurement or MRM, is discussed at length below. Third, coordination between the CIMMYT

[25] These were embodied in the very different nature and incentives of the two field teams. The CIMMYT field staff used a largely top-down approach. They measured success in terms of number of demonstrations and farmers attending them. The iDE staff was more customer/client driven, and measured its outcomes in terms of machines sold and machinery services used.
[26] CIMMYT as an institution is organized to conduct focused and targeted research projects and implement traditional development projects, and it was difficult for the organization to pivot as quickly as was necessary with adaptive management.

and iDE field teams needed improvement; lessons learned and best practices were not being shared fast enough. The new COP replaced the leadership of all the field teams, the COP and DPM worked together to facilitate regular CIMMYT/iDE meetings at both the field and Dhaka level with a focus on emerging lessons and tactical pivots, and the project launched a "Digital CSISA-MI" campaign to use ITC to share information.[27] This strategy was successful in making a great deal of information available as needed to all team members.

Additional challenges to adaptive management included:

- Filling staff positions was slow due to lengthy human resources processes.
- iDE both originally designated their private sector engagement team as part-time, and their responsibilities were split with other projects, but this allocation proved inadequate to the task. The client relationship management, communication at the Dhaka and field levels, troubleshooting of agreements, and solving supply chain challenges required full-time intervention managers. Three dedicated intervention managers replaced the two-person, part-time private sector engagement team.
- Machinery needed modifications and adaptation. As noted above, machinery was initially selected by CIMMYT experts in consultation with BADC experts. This led to the selection of some machines that did not interest farmers, or particular versions of machines that had problems, which was the case with both the initial versions of AFPs and reapers.[28] The project changed its approach to importing and field testing machinery with real farmers and LSPs before encouraging its PSP partners to place a commercial size order.
- Some of the PSPs preferred to sell to the public sector. Historically, private machinery companies have often sold machines based on tenders and contracts to either donor or GOB projects, with no risk and guaranteed profit. When ACI and RFL found themselves with surplus reapers and AFPs after the first seasons, both made successful efforts to sell to the GOB. For example, AFPs were sold to nearby dredging projects.
- Dealers, especially those working for companies (e.g., RFL) for whom agricultural machinery was a sideline, lacked the product knowledge and the incentives to sell machinery.

It became apparent that the two-track approach, and the internal project-set requirement that 25 percent of effort had to be focused on wheat, maize, and fallow land, were undermining the project's ability to achieve significant traction and adoption. The new COP lifted this constraint and also encouraged greater targeting to scale up intensively rather than extensively, seeking to create a critical mass in selected locations. The number of upazilas had increased in Year 2.[29] As a result, in Year 3 iDE decreased the number of upazillas in which it was working.[30]

CSISA-MI made other important changes in sales strategy and activities as well. These included:

[27] For example, the iDE DPM pushed to get all of the iDE staff using Google Calendar to track their activities, and Google Drive to track JVAs, reports, and MRM data (the MRM system is described below).
[28] For example, there were three key problems with the first batch of AFPs. First, RFL ordered a thinner gauge pump than what CIMMYT ordered and was demonstrating, so many purchasers of the RFL pump were unhappy to learn they had purchased an inferior machine to what they expected. Second, RFL ordered about 200 direct coupling pumps which do not work with the diesel engines LSPs usually use. Third, they ordered 4-inch diameter pumps, but it became clear over the course of the sales season that many gher and boro block managers want 6-inch or larger pumps to move maximum water fast. As a consequence of having ordered too many of the wrong-fit AFPs, RFL and CSISA-MI became locked into having to promote them, which demotivated RFL sales staff and CSISA-MI field staff.
[29] By end of Year 2, CIMMYT had spread from 36 upazilas to 61, and iDE had spread from 31 upazilas to 74. CIMMYT and iDE were active in 135 upazilas, but sales occurred in only 104.
[30] Interviews with iDE implementation team.

- The project hired temporary sales staff to supplement PSP dealers. This proved to be unsuccessful because staff hired were young, lacked product knowledge, and had no company loyalty. Pay was low and with inadequate incentives.
- Adding additional partners to RFL and ACI. Working with new partners – such as Metal (which sold reapers initially and eventually AFP too) and Janata Engineering (which sold PTOS and was interested to pilot power tiller operated reapers) – was successful in that it brought companies with a greater focus on only machinery and provided both competition for the initial partners and reassurance from other companies that there was potential in this market. The whole relationship with PSPs is discussed at greater length below in Section VIII.
- Identifying the timing of marketing events. Events such as shop branding, video shows, and haat bazaars must start well in advance of sales season to be effective. They also found that the impact of marketing activities can be delayed: demonstrations and video shows this season may not convert into sales until next season, especially as LSPs tend to buy only when they have cash flow from a recent harvest.
- Analyzing and tracking how individual events impact overall sales. They introduced discount coupons and other tools tagged with particular events.
- Improving messaging on technologies among project and PSP staff. The project introduced "job aides" (e.g. sales guide, videos and pictures, and "Frequently Asked Questions") to keep messaging consistent and high quality.
- The initial training of LSPs in how to use machinery was not enough. Some LSPs, particularly new ones, had difficulty in generating enough demand for their services, i.e., doing their own marketing. The project introduced in Year 2 business planning training, to help them identify and target their customer base and create a market for their machinery services, and later financial management training.
- The project needed to support spontaneous diffusion more actively. In Year 2 and especially Year 3, "copycat" LSPs came into existence; there were 60 LSPs who did not purchase their machinery through the project and did not use the seed box. The project extended technical and business plan training to these LSPs to help promote the profitability of the newly discovered tilling/seeding combination.
- While the project has been very careful to avoid fully subsidizing either PSPs or farmers, it discovered that in some cases (i.e., for AFPs), initial subsidy levels were too low, and for more expensive machinery such as seeders and reapers, low-cost financing was needed to accelerate sales. It increased subsidies on AFPs, worked to get GOB subsidies of reapers, and introduced subsidized financing in partnership with local MFIs. The issues of subsidies and financing are discussed at greater length below.

VIII. THE EXTERNAL CONTEXT AND SPACES

A. Public Sector Role

The public sector has affected the scaling up of agricultural machinery in three dimensions. Public sector research institutions, particularly BADC and to a lesser extent the Bangladesh Rice Research Institute (BRRI), have done extensive research, development and testing on machinery, including a version of the PTOS currently being scaled. DAE has provided subsidies for the purchase of agricultural machinery in the past, which significantly supported the widespread adoption of power tillers, and has recently introduced new ones, including for some of the machines being support by CSISA-MI—including SPRs and some versions of the PTOS. Finally, DAE has been active at the field level in the form of SAAOs doing their own machinery demonstrations, loaning machinery to farmers to try, participating in CSISA-MI demonstrations and promotional events, and advising farmers on the purchase of machinery and the use of machinery services.

Over the last 25 years, BADC and BRRI have developed designs for over 30 types of agricultural machinery specifically designed for the Bangladeshi environment.[31] The institutions provide these designs to domestic manufacturers for production, particularly small workshops and cottage industries. While the designs are provided for free, machinery producers are required to sell them at a price which is fixed on a cost-plus formula jointly determined in discussions among BADC, BARI, BRRI, machinery producers (mostly cottage level), and other stakeholders.

Few of the publicly designed machines have gone to scale or been widely adopted commercially.[32] There are several reasons for the low adoption rate. First, the design approach is very top-down, driven by experts' opinions even though there is some feedback from farmers. This results in machines that farmers often find difficult to use, despite iterative modifications based on farmer feedback. This is reinforced by the fact that machines are usually fabricated out of cast iron or steel because Bangladeshi production ability is not yet up to working in materials like aluminum. While these materials are more durable, they are extremely heavy and difficult to maneuver and transport in comparison to imported machinery from China, Thailand, and India. Second, BADC's demonstration and marketing efforts are very limited. BADC does its own demos, often in the context of GOB programs to improve agricultural productivity, and also lends machines to local farmers. However, these efforts neither ensure that there is a producer making and distributing the machines nor connect interested buyers with producers or dealers. Even if farmers were interested, there is no easy mechanism to buy the machines. Farmers receiving trial machinery are largely selected based political connections or personal connections through friends and relatives.

BADC and BRRI are more significant in their potential ability to block donor or private efforts to introduce machinery than in what they can contribute positively. They influence which machines are eligible for GOB/DAE subsidies. Machines receiving subsidies usually have to be subject to testing and approval by BADC. The CSISA-MI project has been careful to submit new machinery for testing to gain GOB support, or at least avoid opposition, and to include BADC and DAE staff in its awareness-building and demonstration efforts. Both CIMMYT and iDE have on staff former senior leadership from DAE, BADC, and BRRI who have played an essential role in maintaining support from and harmonizing relationships with those institutions. In particular, along with some senior PSP management that is politically well-connected, these staff members have been instrumental in getting DAE approval of subsidies on reapers and certain types of seeders.

Public sector subsidies for machinery have played an important role in mechanization historically and are likely to do so in the current process. The scaling up of power tillers and tractors accelerated in 1988 after the GOB virtually eliminated tariffs on imported agricultural machinery. Over the ensuing decades, the GOB subsidized the purchase of those machines for various periods, culminating in an active mechanization support program from 2009-11. During this period, power tillers and tractors were subsidized at a rate of 25 percent off the suggested retail price. Over 34,000 power tillers were subsidized over the life of that project. In 2012 GOB stopped the power tiller subsidy program.

In 2014 the GOB instituted a new machinery subsidy program with subsidy levels set at 30 percent of the purchase price. By the end of 2015 the subsidized machinery included seeders, four-wheeled tractors, combines, threshers, rice transplanters, and SPRs. In principle, machinery is selected for subsidies based on a demonstrated demand from farmers, i.e., subsidies are demand-driven. Subsidized machinery must be approved by GOB and tested by BARI or BADC, then the manufacturers/importers themselves must apply for approval as well. To be approved, companies need to demonstrate that they

[31] Interview with Head of BADC machinery division.

[32] The machines that have been the most successful have been two versions of threshers, a maize sheller and, to a lesser extent, a potato harvester.

have a viable network of dealers so that farmers can access machines. In the near future companies will be required to train mechanics to ensure availability of repairs and after-sales servicing.

CSISA-MI also offered subsidies on all the machinery, at least until late 2015 when DAE subsidies started to become available. Most interviewed LSPs appeared to be quite sensitive to prices because of the capital or cash flow required, especially for machines at higher price points, i.e., seeders and reapers. The vast majority of early adopters have benefited from subsidies, whether from DAE or CSISA-MI. This has been particularly true of reaper purchasers.

At the same time, the effects of public sector subsidies are constrained by the fact that the DAE only offers a limited number of DAE subsidies based on budget constraints.[33] Public sector subsidies (and certainly CSISA-MI subsidies) appear to cover a fraction of overall demand, let alone potential demand. As overall demand grows, the share of purchases receiving subsidies is likely to shrink.[34]

In principle, only poor farmers, defined as those having less than two acres of land, are eligible for subsidies. Often farmers with that little land lacked the means to buy a machine even at the subsidized rate. However, it seems that the eligibility criteria are often not applied. According to all of the review team's GDs with farmers, the majority of subsidies are allocated to friends, neighbors, and relatives of the DAE staff. According to interviews with one agricultural machinery company, applicants are required to pay a BDT 5,000 "processing payment" to the SAAO as part of their application, particularly if they are not connected.

Only two of the machines being scaled by CSISA-MI are eligible for public subsidies. One machine is the PTOS, although the BADC version that is eligible for the subsidy is not the same as the version being imported and promoted by private sector partner RFL, illustrating the role of BADC.[35] The other machine eligible for subsidy is the reaper. As the reaper subsidy was only approved at the end of 2015, only 100 have been sold with subsidies to date, but another 1,000 subsidies have been approved and 4,000 applications are in the pipeline.[36] It appears that if the PTOR performs well during the boro rice harvest which goes from late April through May, subsidies for the PTOR may be approved.

DAE has been active in recent years and in partnership with CSISA-MI in demonstrating and promoting machines, though the level of effort and impact vary widely across districts. According to an interview with the DAE deputy director in the Barisal region, the DAE in Barisal demonstrates publicly supported machines in each upazilla at least three times per year, usually to between 50 and 100 people. Despite their constraints, a GD with six SAAOs[37] reported that they are actively promoting machines and

[33] The review team was not able to obtain information on what the total budget allocation is for machinery subsidies in general, or for power tiller/PTOS and reaper subsidies in particular.

[34] There is a fixed number of subsidies for each type of machine at the national level. These subsidies are then allocated to DAE offices at the region and district level. In other words, each DAE district has a maximum number of farmers to whom it can offer subsidies for each type of machine, e.g., 3 combines, 5 transplanters, 15 seeders, etc. To get one of the subsidies, farmers must apply to the local DAE office. The local DAE office reviews the applications and approves a number of applications conforming with the number of subsidies it has available. This list is then sent to DAE headquarters for approval. Approval is then sent back to the local level. Once farmers have applied and been approved, they are sent the list of the approved models and distributors of that particular machine and the specific names of dealers in their area. Farmers go to those dealers and buy the machine at the subsidized price, then DAE reimburses the dealer. The subsidy is fixed on percent of the MRP, but farmers can negotiate lower prices.

[35] To receive a PTOS subsidy, a farmer must buy the PTOS and a power tiller at the same time, which combined would usually cost around BDT 140,000 ($1,800) even with the subsidy. As of this writing in April 2016, only 50 such power tiller/PTOS packages have been sold, all of which include power tillers imported by Chittagong Builders.

[36] Interview with Ministry of Agriculture officials.

[37] The front-line agricultural extension workers are called SAAOs, and there is one SAAO per union or for about 1500-2500 farmer households. SAAOs primarily advise farmers on the selection of varieties to plant, when to plant and harvest, and how

participating in CSISA-MI awareness building and demonstration events. According to a GD with one group of small farmers in Barisal, the opinion of their SAAO is actively sought, and she influences their decisions to buy both machines and machinery services. Interviews with SAAOs, DAE directors, and GDs in Faridpur revealed that the DAE is less active there in promoting machinery. This was echoed in other GDs in other districts. In a GD with farmers from another area, several ironically suggested: "The DAE should be replaced by iDE Bangladesh [one of the implementing partners of CSISA-MI.]." Only one farmer reported consulting an SAAO there, and in a GD with six SAAOs, despite their efforts at promoting their machines, half acknowledged that they had little impact.

In summary, the public sector has played a mixed role in supporting scaling of agricultural machinery. The elimination of tariffs on imported machinery opened the doors to the large-scale take-up of power tillers. The public sector has similarly facilitated the widespread use of shallow tube wells, centrifugal LLPs, and the diesel engines to drive them. This contributed significantly to the large installed base of power tillers and diesel engines that has been a critical precondition to the introduction and adoption of PTOS and AFP, and possibly PTOR in the future. The national research institutions have been much more of a mixed bag, favoring their own machines and serving as a gatekeeper for GOB subsidies and support, while engaging in very limited demonstration activities.

The same is true for the subsidies. The presence of public subsidies clearly makes machines more affordable to a price-sensitive and highly cash constrained market, but they also encourage farmers to delay their purchases until they can get approved for a subsidy, and the approval process itself is subject to significant delays. However, the limited number and politically influenced allocation of subsidies suggest that they may be going to people who either could already afford machines or who do not need them. There was a widespread consensus that many of the people who buy machines with GOB subsidies resell them at prices only marginally lower than full market prices, suggesting that the potential positive influence of subsidies in lowering initial purchase prices to early adopters is offset by rent seeking.

The influence of SAAOs probably has the most potential but limited and uneven impact. Partly this is due to regional and district management and the extent to which SAAOs see themselves as rent seeking and resource extractive rather than supporting farmers. It appears that those individual SAAOs who are effective in promoting machines are older and have a proven track record with farmers in their union in recommending new technology or GAPs, i.e., they are trusted. Their effectiveness is also influenced by demand; that is, unions with acute labor shortages are more likely to adopt machinery. However, there appears to be no relationship among adoption, SAAOs, and the number of power tillers per 100 farmers in their unions.

B. Monitoring and Evaluation and Monitoring and Results Measurement

CSISA-MI launched with a monitoring and evaluation system geared to reporting on required FTF indicators, which by and large does not include either market performance measures nor socio-economic market data. Although project leadership recognized the importance of putting an MRM in place, they prioritized other matters more immediately relevant to getting machines into the market and working toward hitting Year 1 sales targets. In Year 1, CIMMYT's Microsoft Access-based monitoring and evaluation (M&E) system was used to meet USAID FTF indicator reporting requirements. The

to address problems with disease and pests. They have little experience with agricultural machinery. Despite recent efforts at rectifying this through trainings provided by DAE, according to interviews with CSISA-MI field staff SAAOs remain generally lacking in expertise regarding agricultural machinery, especially newly introduced machines. SAAOs receive BDT 200 (less than $3) per month for fuel from DAE, and are required to provide their own transportation (motorcycles, bicycles, or "public" transportation). Because of this lack of transportation support from DAE, the frequency of their interaction with farmers is limited.

original indicators were drawn from CSISA-BD and were measured on a quarterly basis. They included number of farmers adopting the agricultural services and number of hectares under improved technologies. The targets were insufficient as a barometer for the overall functioning of the market system and did not support the real-time data requirements of adaptive management.

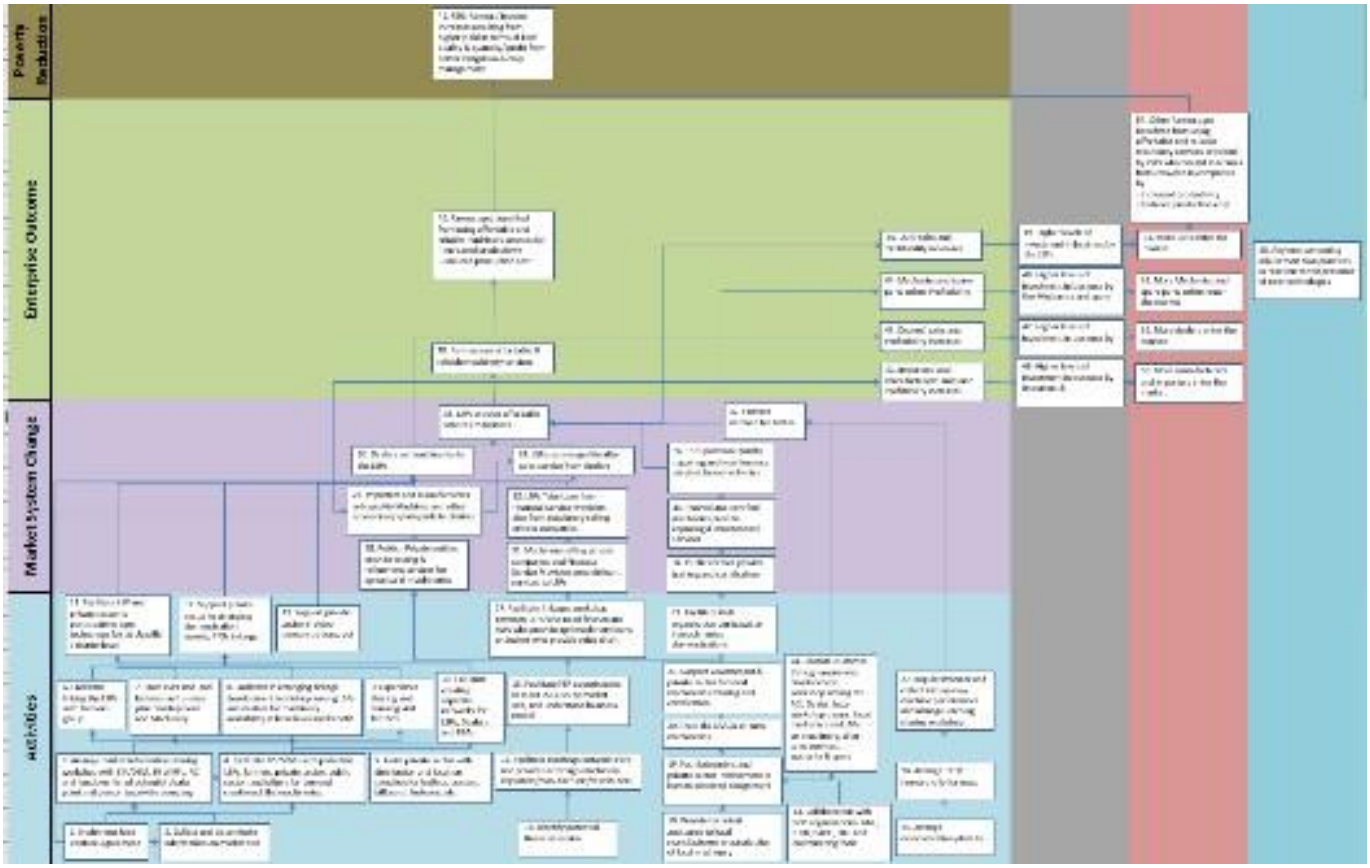
As noted above, given the surprises and unexpected outcomes of Year1, and the subsequent strategic pivot, it became apparent that an MRM system was necessary to collaborate efficiently and track the project's technology and business model interventions as the technology moved through an "S-curve" of adoption. It was not until Year 2 of the project that they turned their thinking to the design and implementation of the MRM. An initial system was rolled out in the second year of the project, and staff further improved that system in Year 3 (Annex C provides CSISA-MI's MRM strategy).

C. Partnerships

1. Partnership between CSISA-MI and Private Sector Partners

CSISA-MI's attempt to find private partners using objective criteria[38] proved difficult with unknown products and a risky investment proposition; initially at least partnerships with the private sector were established based primarily on pre-existing personal relationships.

FIGURE 7: SAMPLE RESULTS CHAIN



Source: CSISA-MI Project Documentation

[38] The objective criteria were for companies with large market share and size, large capital resources, an appetite for risk, and significant distribution networks in the FTF ZOI.

There were several challenges in the first few years of these partnerships.

- CSISA-MI represented a very small portion of their sales and was therefore a low priority for these large partners.
- The large partners had some experience with donor projects and expected that they would get money and assistance without putting any of their own money on the table; RFL and ACI assumed they were essentially being paid to participate, and were confused to find out that for CSISA-MI this was not the case.
- The PSPs believed that CSISA-MI had contractual obligations to work with the private sector and used this in bargaining with the project on the size and scope of the relative contributions. This adversely affected incentives and efforts to make the project commercially sustainable from the beginning.

Formal agreements played an important role in partnerships with the private sector. In Year 1 the relationships were established via formal letters of agreement (LOAs). The LOAs turned out to be a less than optimal means of engagement, because they inadequately articulated the responsibilities, timelines, and budgets; they agreed to pay the companies up front for cost-split project activities; and they functioned like a contract the companies were expected to fulfill and be compensated for. CSISA-MI found that dictating terms to the PSPs in order to meet project goals failed on nearly every front. In Year 2 the project switched to a joint venture agreement (JVA) model grounded in activities that were in line with the company's goals and perception of value added and were more adaptive in nature. The JVAs captured the spirit of co-investing, capacity building, and risk mitigation via a cost reimbursement model, and more clearly articulated responsibilities.[39] To avoid future over-purchases of machinery or over-commitments, they approached the JVAs as less prescriptive, and more adaptive. They used the JVAs to captured key objectives, responsibilities, and financial contributions, and then amended the JVA over the course of the year as feedback from the market suggested better strategies.

A major feature of the CSISA-MI partnership with the private sector has been the very time and labor-intensive nature of those relationships. Maintaining the relationship, negotiating terms, and updating the JVAs on a rolling basis required full-time staff.

As the project has progressed and partners have been added, it has become clear to CSISA-MI that many of these issues were worked out through successive JVAs and working relationships. Starting with large companies appeared to make sense. There was already a basis for trust formed through the prior personal relationships, and they were large enough that the financial contribution and risks involved were minimal compared to their overall sales, capital resources, and brand. At the same time, adding additional companies, smaller companies, proved to be important. By the second year of the project, the increased sales seen by participating companies were a sufficient incentive to voluntarily participate in project activities. Once smaller companies saw some initial success, additional companies such as Metal and Green Machinery approached the project about partnering as well.

The addition of Metal, Alim Industries, and Janata Engineering increased competition, allowed for the broadening and deepening of the sector, and greater cost sharing. The project set the goal of partnering with two companies per technology to leverage benefits of competition (diversity of supply, quantity, quality, and price of machinery) in the market place (RFL and Metal for AFP; RFL and independent

[39] The project also found that "cost-sharing," instead of "cost-splitting," was an important distinction. In the LOA model, the project covered some costs, while the PSP covered others. In the later JVA model they shared costs for each planned event, which achieved the same results but gave the PSP an ownership stake in each activity implemented. When CSISA-MI found in Year 3 that companies tended to play it safe in focusing activities in their comfort zones, the project decided to independently pilot innovations that it prioritized, so that the companies could see it work prior to adopting it.

dealers for PTOS; and ACI and Metal for reaper). They found that working with competing companies had the benefit of diversifying the supply of machines to the region, so if one company's order arrives late or their stock runs out, the presence of competitors ensures supply in the market. The project did find that working with competing companies necessitates a new level of diplomacy and skill to the customer relationship management, and that partnering with more than two companies per technology would likely be a significant strain on project resources. Similarly, the project found that work with both dealers dedicated to specific companies and independent dealers was fruitful. It not only increased sales; it sent signals to non-JVA companies (e.g., Chittagong Builders and Green Machinery) that there is market demand for these technologies.

2. Partnership between CIMMYT and iDE: Function, Challenges, Lessons

The partnership between CIMMYT and iDE Bangladesh grew out of their experience working together in CSISA-BD and a recognition of their complementary strengths. The complementary strengths between CIMMYT – a research institution – and iDE – a market facilitation NGO – were essential to the success of CSISA-MI. As a CGIAR center and PIO, CIMMYT brought numerous advantages to the partnership. It was able to receive grant funding from USAID without competing for it, and on very short notice. CIMMYT's agronomic expertise and extensive prior research on agricultural machinery relevant to SW Bangladesh played an important role in the initial identification of machinery with market potential. iDE was essential in bringing the relationships necessary to establish relationships with PSPs. Their market systems expertise was essential to establishing the model through which the project worked. Their organizational flexibility was key to being able to staff up quickly in response to an aggressive project start date and to changing strategy and tactics over time with the experience of each sales season.

The CIMMYT/iDE-B partnership had several strengths that contributed significantly to the ultimate success of CSISA-MI and scaling up, in addition to their complementary core competencies in agronomics and market facilitation. Both had existing presence and relationships with key stakeholders on the ground that predated CSISA-MI. This allowed them to spend a year prior to the actual award preparing for implementation, and in particular lining up PSPs and getting buy-in from the GOB. Had they arrived to start up a project from scratch, it would have taken more than a year for implementation to get going. In fact, CSISA-MI might not have been viable at all because it is doubtful that RFL and ACI would have partnered with the project without the existing personal relationships.

A second strength of the CSISA-MI partnership was the fact that though CIMMYT was the prime, it gave roughly half the resources to iDE and the lead role in the market side, which ultimately proved to be the most important part of the project. In part this reflected the appreciation and understanding by CIMMYT leadership of the importance of market facilitation and a recognition of their own weaknesses in that area; business as usual was not likely to achieve the desired results.

Nonetheless, and despite a very good relationship between the CIMMYT and iDE-B leadership working on CSISA-MI, the differences in organizational culture brought with it significant challenges in the early years. Once the first year 'surprise' results were in and USAID had approved a more flexible approach, iDE wanted to move to a much nimbler, adaptive implementation approach that used regular market feedback to adjust tactics. There were also differences in their approaches to monitoring outcomes, the speed with which new staff could be recruited and hired, whether to make decisions based on the opinions of agronomic experts versus the experience of farmers and HCD, whether to run traditional demonstration projects or use a business sales/leads/follow-up approach for marketing.

A new COP was hired after 18 months who had greater project management experience, and many of these issues were able to be addressed by him. Even though he was also a technical expert and veteran

of many CGIAR institutions, he had as his primary goal delivery the results that the Mission wanted – scaling up of machinery services through private sector partnerships and commercial pathways, regardless of sectors. Thus he replaced field managers who were demonstration vs. market oriented, and instituted new policies so that all future machines were first imported and field tested with farmers.

In addition to each organization's unique strengths, which made them well-suited as partners, both organizations unequivocally state that the success of the project is ultimately owed to the dedication, championship, trust, and working relationships of a few key individuals from each organization. It required a great deal of trust for CIMMYT in particular to embrace the market systems approach championed by iDE, as it was far outside their traditional methods of operation. However, their project manager had established relationships and trust in iDE's leadership team. Both CIMMYT and iDE credit these relationships and this trust as the true success behind establishing the CSISA-MI project.

D. Financing

Financing of agricultural machinery in Bangladesh is quite limited. The most common source of financing available is from the banking sector. All the interviewed farmers and LSPs stated that they avoided borrowing from banks if at all possible because of the relatively high interest rates and, more importantly, the very high transaction costs. They consistently complained that the amount of paperwork required was incredibly onerous, especially for a semi-literate or illiterate farmer, and involved numerous, expensive, and time-consuming trips to town as most banks do not have branches in rural areas. Filling out a loan application requires paying a filing fee.

The less onerous option for many farmers is borrowing from MFIs. However, most MFIs only loan to members, which are nearly 100 percent women, whereas almost all LSPs are men. They also mostly make loans of six months' duration for short-term investments or cash flow needs, i.e., to buy inventory for market women or to pay school fees. This does not fit with the repayment periods that most of the machines require, especially at full price.

All of the machinery companies involved in this project only sell machines to dealers, not directly to consumers. Some dealers offer financing, but only to farmers they have known for a long time and with whom they have a good and trusting relationship. When asked why they were willing to do this, several commented that they were sure that the machines were profitable, though this did depend on the skills of the LSPs themselves, so that they were more inclined to lend to an existing LSP, i.e., someone who already sold power tiller services. They also said that in the worst case if they had to, they could repossess the machine and hire an operator, and recover the costs that way. There are conflicting reports on the existence of a secondary market for machinery in SW Bangladesh; many interviewees reported, and in fact there is strong social pressure not to buy a machine that has been repossessed from a friend or neighbor.

Farmers in Bangladesh prefer to finance their investments and cash flows from their own activities or by borrowing from extended family. Most of the LSPs who borrowed money to buy their machines in the first two years reported that this was their source of borrowing. This was especially true for the younger farmers, who are the most common demographic purchasing the machines; they often borrowed from an older uncle or parent.

In this context, CSISA-MI believed that informal finance would be sufficient for early adopters, particularly given the subsidies being offered by the project. By the second year, it became apparent that the ability for scaling up to accelerate was constrained by access to finance, particularly for the reaper, given it costs 3.5 times as much as the seeder. In this context, CSISA-MI negotiated arrangements with a few MFIs to offer zero-interest loans to LSPs to buy machines, with CSISA-MI covering the difference between the normal interest rate (around 12-22 percent, depending on the lender) and zero. This was

meant as a promotional offer to early adopters and to further incentivize MFIs who were less experienced or comfortable making loans for agricultural machinery.

As a result, the MFI partnerships worked best with three MFIs: TMSS, JCF, and SDC. TMSS has financed the majority of reapers bought in the past six months and several seeders as well; in year 3 these three organizations provided 82, 23, and 22 loans, respectively. The most successful partnership, with TMSS, was productive for several reasons. First, TMSS is one of the very few MFIs that was already making loans for agricultural machinery, and was eager to expand its portfolio. Second, TMSS has branches that are geographically distributed over a wide area with good rural coverage. TMSS has worked to minimize the transaction costs (e.g. having to make multiple trips to a city throughout the loan process) that have caused many farmers to avoid bank loans. When machines are financed, they are delivered to farmers at their homes and accompanied by TMSS staff as well as technical staff of the dealer. Third, TMSS has developed loan products whose duration and repayment schedule, while not perfectly aligned with the cash flow of LSPs, is a much better fit for LSPs than the loan products offered by other MFIs. Finally, TMSS has been willing to invest heavily in training appropriate staff for this kind of lending; because of the large size of the loan, both branch and district managers visit farmers after loan approval but before the loan is finalized.

Despite this success, there have been several challenges for TMSS lending. First, only landowners are eligible for loans. This is because TMSS is afraid that a landless borrower would abscond with the funds or the machine. While it is true that those farmers who are totally landless (many both own and lease land) are unlikely to have the means to borrow, this restriction does limit the pool of borrowers. Second, borrowers must be members. TMSS has gotten around this by having borrowers join a pre-existing savings and lending group (SLG). Third, TMSS requires a group guarantee from the SLG. While it may seem odd that an SLG is willing to co-guarantee someone who has joined the group, TMSS claims that this is not a problem.

In addition to the zero-interest loans provided by TMSS and other MFIs, project staff worked with two PSPs: ACI and Metall. These programs did not prove satisfactory to the companies because several recipients of loans for reapers had difficulty with repayment, creating friction between ACI and its dealers and between the dealers and their customers. (In contrast, ACI and others have and continue to run a successful tractor lending program; the difference appears to be that the higher price point allows for proportionally lower transaction costs and a higher return on investment). ACI reverted to providing commissions to TMSS to make loans on their behalf and manage the loans and collections. This has proved satisfactory to all parties.

The fact that most reapers have been financed shows that the lending program has been a success and important for machines at high price points. It is also likely that the lending program has expanded the pool of borrowers, though the impact on seeders is not clear. At the same time, CSISA-MI discovered that the lending program can only be scaled up by adding MFIs, in large part because most MFIs have a narrow and small geographic coverage. Moreover, most MFIs did not have the staff capacity or capability to easily roll out new products or old products to new customers; implementing machinery lending required hiring and training new staff at great expense. As a result, CSISA-MI developed Joint Venture Agreements to cost-share the expense of developing and rolling out an agricultural machinery lending product and program for the first year. This proved highly effective and led to a large increase in the number of loans made in year tjree.

From the borrower perspective, most borrowers have said that they would not have borrowed from TMSS or other MFIs without zero interest rates. Obviously this means that such loans are not sustainable in the medium-run nor capable of financing large numbers of LSPs, but do seem to be a helpful tool in kick starting early adoption.

E. Strengthening the Supply Chain: Warranty, After-Sales Service, Mechanics, and Spare Parts

In the case of scaling up agricultural machinery, it is not sufficient to sell machines, but also to provide for after-sales servicing and spare parts. This is particularly essential for LSPs providing machinery services, as the land preparation and harvesting services are in a very small time window and any delays cost them (and their clients) time, money and reputation. In the CSISA-MI case, added urgency was the fact that almost all the machines are imported, so that in most cases spare parts need to be imported as well, with significant lead time.

In Year 1 it was discovered that after sales service being offered through ACI and RFL was insufficient for three reasons: 1) technicians were not appropriately trained on new technologies; 2) there were not enough technicians dedicated to new product support; and 3) support from the companies, although free, often did not come quickly enough. Because of the very short length of time in which crops can be harvested, the loss of a day or more waiting for a machine to be repaired can be a significant loss in revenue and potentially in crops as well. The project team found that some farmers would be willing to pay for repairs from a private mechanic if it meant they would not lose so much time in the field. CSISA-MI determined that in addition to more machine-focused training and technicians being offered by the PSPs, the project also needed to train local mechanics outside of companies to bolster service availability.

CSISA-MI developed a three-pronged strategy for addressing maintenance and repair challenges: (1) working with lead PSPs; (2) working with other market actors such as spare parts shops and local mechanics; and (3) linking local, rural market actors, such as spare parts shops to sources of quality parts in Dhaka. To date, CSISA-MI has worked with 36 local spare parts shops, 15 local spare parts suppliers, and 2 importers/suppliers in Dhaka.

F. Organization of Farmers in Southwest Bangladesh

Unlike FTF projects in many other countries, farmer associations have not been a major conduit for reaching large numbers of farmers in SW Bangladesh. This is because, with the exception of irrigation blocks, there are few formal associations that play a significant role in agricultural production in the region. Irrigation blocks for boro rice, while important, are largely limited to irrigation services.

Other than Blocks, the only farmer structures that seemed to play something of a role were Integrated Agricultural Productivity Project (IAPP) committees. These were created by the government at the village/union level. They are composed of 50-60 farmers who work with the SAAOs and get trained on safe food production, using less pesticide, and advising farmers on which varieties of seeds/crops are appropriate for their agro-ecological conditions. Some of them have devolved into smaller groups dedicated to discovering new technologies, but it was not clear how widespread or important these were, as the review team only heard mention of them a few times.

IX. USAID OVERSIGHT, MANAGEMENT, AND ACCOUNTABILITY

USAID's oversight and management of the CSISA-MI project was critical in supporting the project's efforts to pursue a market-driven, S-curve, adaptive management approach to scaling up. This is for three key reasons. First, despite the political reality that USAID projects are expected to achieve large numbers quickly to measure success and maintain their funding, the Bangladesh Mission took a risk on CSISA-MI knowing that it was unlikely that the project would hit its initially ambitious adoption targets. It took a portfolio approach to managing the project – that is, it had a large portfolio of established

projects meeting or exceeding their numbers, so low numbers from CSISA-MI were less conspicuous and politically objectionable.[40] The Bangladesh Mission was fully committed to achieving a market systems approach, and so allowed CIMMYT to set new, more reasonable targets when it became apparent that the initial targets were too ambitious.

Second, although the Bangladesh Mission staff had a clear vision for taking the market systems approach to scale, they understood the limitations of their own implementation experience, and decided to collaborate heavily with the private sector to achieve their vision. They selected partners with a good understanding of the agronomics and machinery (CIMMYT) and market systems and scaling (iDE), and co-designed the project with the flexibility to adjust strategy according to market response. Third, there was an attitude of partnership and co-creation between USAID and the CSISA-MI implementing partners. The Bangladesh Mission viewed its role as that of a remover of barriers, and actively engaged stakeholders and financial partners to address constraints in order to help CSISA-MI succeed.

It appears that CSISA-MI was lucky that the project was financed through a field grant because of its expediency and its flexibility. However, the risk in a field grant is the lack of accountability on the part of the implementing partner to USAID. Although the agreement between USAID and the implementing partners is a field grant, and the implementing partners do not have to get approval from USAID for changes in strategy or activities, CIMMYT and iDE regularly report to the Bangladesh Mission on the project's progress, and consult closely with the Mission on adjustments to strategy activities. This relationship was entered into willingly on both sides in a desire to make the project work. Although it would be possible to achieve the same degree of flexibility with a contract, it would require the commitment of the contracting office to establishing the collaborative relationship, and would further require great care in crafting the project design. Too prescriptive of a design would result in the project's inability to adapt to market needs; however, too flexible of a design would leave the contract vulnerable to future protests from unsuccessful bidders. In hindsight, the Bangladesh Mission staff believe that a cooperative agreement likely offers the best balance of accountability and flexibility to pursue the kind of approach exemplified by CSISA-MI.

The Bangladesh Mission's support of CSISA-MI's approach presented several challenges. It required a commitment on the part of the Mission's team to invest the time and energy to figure out how to implement the project successfully with a hitherto untested approach, and how to get support from Mission leadership for the low early numbers. In particular, the Mission worked with CSISA-MI to significantly revise the work plan on an annual basis, based on the outcomes of the previous year. In retrospect, the Bangladesh Mission staff involved with program oversight described the ideal program description as: sensitive to the operating context, but not prescriptive in approach; a description of the change that stakeholders want to see; and a description of the "meta process" for how USAID and the implementing partner will collaborate to co-create the work plan as the project progresses, based on real-time market feedback.

A final challenge has been M&E. USAID has traditionally focused on indicators that provided for accountability and that could be rolled up across all country programs for reporting purposes, such as number of beneficiaries reached or amount of money/equipment/food dispensed. Despite the recent additions of market-oriented indicators such as gross sales and profit margins, the CSISA-MI project and the Mission discovered that there were significant gaps between FTF indicators and those required for adaptive management of a market systems project. For example, additional indicators might include successful commercial buy-in/ownership (e.g., significant indirect beneficiaries, copycat machines, private sector investment, mid- and late-project private sector adopters, scaling outside the project ZOI,

[40] Indeed, according to the Mission staff, if this had not been the case, they would have been less likely to support CSISA-MI's approach.

domestic manufacture of previously imported inputs, etc.). Although these indicators are highly project-specific and do not roll up across portfolios, regions, or globally, it is critical that such indicators are designed and used to evaluate project success and impact of market systems projects.

X. CONCLUSIONS AND LESSONS LEARNED

A. Country Context Factors and Scaling

By and large, the country context in Bangladesh facilitated scaling up of agricultural machinery services. Perhaps most important was the emergence of a chronic and increasing shortage of agricultural labor, especially around peak demand periods of land preparation, planting, and harvesting. This structural need was acutely felt by all the interviewed farmers and LSPs, so that the motivation for adoption was not simply the cost and time savings, and productivity increases, but rather the ability to get key tasks accomplished quickly and at the right times.

A second set of factors that supported scaling was the fact that the majority of farmers in SW Bangladesh already produce a cash surplus in addition to their subsistence rice production. This provides for a commercial orientation that predisposes farmers to be willing to make cash outlays for inputs and services, as they have cash income to pay for them. This was particularly true of the "middle class" farmers who make up the preponderance of LSPs, and the early adopters who grow high value-added cash crops like fish, onions, and garlic. This commercial orientation was reinforced by the fact that most farmers grow at least two if not three crops, and the crops that are not aman rice provide not only cash income but a form of risk diversification across the year, again encouraging a willingness to invest. While it is hard to know for sure, it seems that in other country contexts where the majority of farmers are subsistence growing only staple cereals, and only growing one crop per year, less cash income and higher risks would make adoption less likely. In Bangladesh, these circumstances not only facilitated initial scaling, but also multiplier effects as farmers who adopted machinery services to their highest value-added cash crops in many cases then tried these services on lesser value crops and staple cereals.

Finally, there was a substantial pre-existing base of machinery, LSPs, and farmers with experience using or hiring machinery services. The presence of a large number of power tillers, LLPs, and diesel engines all facilitated scaling up of the AFP, PTOS, and likely PTOR as leveraging existing power sources or upgrading was clearly easier than adopting machinery de novo.

B. Characteristics of the Innovation

The agricultural machinery that was introduced by CSISA-MI allowed for a natural experiment in what characteristics facilitate adoption and scaling up because of the simultaneous introduction of several machines. Based on this experience, the following characteristics were the most important for scaling:

- Upgrading existing mechanization to take advantage of the fact that farmers already had a level of comfort and familiarity with the technology, so that the extent of change required was low (replacing hand labor with machines such as reapers for the first time was much harder);
- Leveraging existing installed power sources (PTs, diesels), which made adoption cheaper and more familiar;
- Requiring little or no change in other agricultural practices or adoption of other inputs/services;
- Affordable price points relative to middle-class farmers' disposable incomes and financial resources (AFPs have proved much easier to scale than SPRs);
- Utilization by multiple crops and seasons (i.e., potential use time combined with ability to generate significant cost savings that translated into high profit rates and rapid repayment periods);

- Utility for multiple crops and seasons, allowing LSPs to diversify the risk of adoption;
- Utility for cash crops and labor-intensive activities (e.g., ghers, tilling, and planting onion and garlic bulbs);
- Benefits that were immediately visible and tangible in terms of cost, labor, and time savings, and perhaps most important the ability to prepare land, plant, and harvest quickly and on time. While some of the innovations have also had a productivity effect, this was less important and took longer to see.

C. Scaling Up Strategy, Activities, and Implementation

The CSISA-MI project introduced many approaches to project design and implementation that facilitated commercially sustainable scaling up. Perhaps the single most important ones were its steadfast commitment to using a market approach and adaptive management to respond to market feedback. These twin commitments, though sometimes challenging, showed up in a number of ways:

- An experimental, trial-and-error approach to what technology would work, primarily based on farmers' reactions and demand.
- Willingness to pivot on which crops, machines, farmers, and locations the project was targeting.
- Insistence on having private sector partners in an at least co-equal role from the very beginning, including PSPs investing significant cash up front (i.e., not 100 percent project funded) while providing incentives for them by co-funding marketing and awareness building.
- Using a virtuous spiral approach that simultaneously created supply and demand at three different parts of the value chain: 1) companies to dealers; 2) dealers to LSPs, and; 3) LSPS to farmers. CSISA-MI addressed new obstacles as they arose or (as existing obstacles became binding constraints) with each upward spiral (increase in scale), thereby allowing for more scaling.
- Recognizing that farmers, LSPs, and the entire supply chain had to have (market) incentives to participate/adopt, and working to make it profitable for everyone and less risky.
- Attempting to minimize the use of free or subsidized products and services balanced with the recognition that some subsidy was necessary for early adopters, from producers to dealers to LSPs to farmers, to mitigate the risk of trying something new.
- Development of a market-based MRM system to inform choices regarding strategy and activities.
- Exploration and introduction of multiple, innovative marketing techniques beyond the usual demonstrations, including bringing in a professional marketing consultant.

In addition to the various activities listed above that primarily focused on successful adoption, the project also engaged in a number of activities to strengthen the supply chain and provide supporting services. These included:

- Building capacity for machinery dealers, sales people, and LSPs;
- Introducing financing linkages to MFIs along with subsidized loans to address cash flow constraints and provide financing;
- Advocating successfully for GOB subsidies;
- Working with companies to put in place quality after-sales services and availability of spare parts; and
- Expanding to multiple PSPs to increase competition and to provide market signals to initial PSPs that others were interested in this market.

D. Business Case and Market Size

The CSISA-MI project did not do formal studies of market size or the business cases for the various machines prior to the start of the project. This omission was quickly rectified, and the analysis showed that there was a business case for PTOS, reapers, and AFPs, with the strongest case being for PTOS.

The same was true for market size. While no formal marketing study has been done, potential market size has been estimated by a number of indirect methods. These included:

- The number of farmers and hectares growing crops to which the seeder, reaper, and AFP were applicable;
- The number of power tillers and diesel engines that could be used as power sources for seeders and AFPs;
- The number of LLPs that AFPs could replace; and
- The estimated labor shortages at peak planting and harvesting seasons.

These all showed that the potential demand in the FTF ZOI was around 40,000 for most of the machines; multiplied by roughly 30 farmers per machine, this translated into potentially over million farmers each. This large potential demand, and the fact that many of the machines could be sold elsewhere, was a key factor in persuading PSPs to work with CSISA-MI and to maintain this partnership during the first few years.

Most of the impact of mechanization was on cost savings rather than greater productivity; the FTF ZOI is a small share of total production for most crops. Taken together, these two factors meant that there was no real risk that mechanization would increase output supply significantly and put downward pressure on output prices. In other words, the cumulative effect of scaling was unlikely to adversely affect the business case for individual LSPs, farmers, or dealers.

E. Spaces

1. Machinery Sector

A key pre-condition for the success of this project was the existence of a dynamic private domestic agricultural machinery industry and especially the distribution system. In Bangladesh, a key part of the scaling strategy was to start with two very large market actors for whom the necessary capital investment was relatively small compared to the overall size of their operations. Even though all of the technology was initially imported, there was still a need for expertise and a distribution network in place to select, market, and service machinery. The fact that all the machinery was initially imported also has its disadvantages; it may undermine incentives for the large PSPs to participate in the market in the medium-run, as their core competency and comparative advantage is in production.

The machinery sector had several weaknesses which may be found in other countries. Sales and marketing efforts are largely passive and limit their activities to posters and branding in dealers' offices, phone numbers stenciled on the sides of buildings, the use of gifts for purchasers, and some activities in local markets and bazaars. Aspirational advertising, the use of media, and using actual sales to develop customer profiles were, among other things, lacking. In areas with smaller and/or poorer farmers there was often a lack of dealers. In many cases, dealers and sales agents lacked specialized knowledge about machinery in general, and the machines being promoted by CSISA-MI. Finally, even though CSISA-MI was very successful in enrolling the support of senior management in PSPs, the transmission of buy-in from top management to middle-management proved challenging. All of these issues were addressed by CSISA-MI during the first three years of implementation.

2. Public Sector

As in many cases the limited capacity of the public sector extension system meant that they played a limited role in building awareness and driving adoption, and most of this was done by the project and PSPs. Similarly, the role of public sector subsidies was not important during the first two years; in those years most of the subsidies came from the project. However, lower tariffs and subsequently public sector subsidies were important for supporting the first wave of mechanization of power tillers and irrigation pumps. In the current example, as adoption multiplies up through spontaneous diffusion, it appears to be the case that public sector subsidies, now in place on SPRs and hopefully PTORs soon, will again play an important role in accelerating adoption. Undercutting this effect is that the quantity of subsidies are limited and access to both extension services and subsidies is adversely affected by widespread cronyism and patronage. While in other countries such subsidies, once in place, have been difficult to remove because of the constituencies they create, the DAE in Bangladesh has already shown the political will to remove subsidies, e.g., power tillers in 2014.

The existence of state agencies or parastatals involved in production or distribution of agricultural inputs has been shown in other cases to create challenges for scaling up through commercial pathways. In the case of agricultural machinery in Bangladesh, the closest candidate for this status is BADC. As BADC does not engage in production, it does not "spoil" the market the way that subsidized rice seed does in Bangladesh. Nonetheless, BADC is the primary, if not sole, source of research, design, and development of machinery in Bangladesh and has significant political influence. For example, BADC created market distortions through its support for its own designs over foreign imports; that had to be addressed and impeded support for imported, competing machines. Moreover, while BADC could not provide significant positive benefits to scaling, it could have been a source of important obstacles. For these reasons, CSISA-MI went out of its way to partner with all relevant government agencies such as BADC.

3. Partnership Space

Partnerships were essential to scaling up of agricultural machinery services in Bangladesh in two forms, between an agricultural research organization (CIMMYT) and market facilitation organization (iDE-B), and between CSISA-MI and its PSPs. The partnership between CIMMYT and iDE-B showed the potential benefits of this kind of partnership, especially given the institutional weaknesses of CIMMYT in marketing, commercialization, and scaling up. One of the reasons this worked well was because the CIMMYT team in Bangladesh (and South Asia) recognized its own limitations in commercialization. As a result, despite being the "prime" in the relationship, they were willing to grant iDE-B a near equal role and significant autonomy. Despite the strengths of this partnership, its ultimate success has required confronting and addressing several obstacles that CIMMYT brought to the table: 1) institutional rigidities, particularly in human resources policies, that made it difficult for CSISA-MI to respond rapidly and flexibly to changing outcomes; 2) an "old school" culture of top-down, agronomic approach of experts telling farmers what to do rather than dialectically responding to market signals and farmer demand; 3) lack of experienced, professional chiefs of parties; and 4) a commitment to work only in specific sectors and crops. While this type of partnership may well serve as a positive example for future efforts to translate CGIAR research into large-scale adoption, it would appear that these obstacles will persist.

The partnership between CSISA-MI and its PSPs, initially ACI and RFL, was one of the key success factors in CSISA-MI's ability to scale successfully through commercial pathways. Keys to that success appear to include:

- CSISA-MI started by partnering with large companies with ample capital resources who were able to tolerate short-term risk in light of long-term goals of expanding market share and their product line.

- The partners had pre-existing connections built on personal relationships and successful experience working together in the past.
- CSISA-MI insisted that PSPs put their own money on the table in terms of investing in machinery, in exchange for financial and in-kind support for sales, marketing, and subsidies.
- Subsidies and co-financing can attract companies to less desirable regions (markets) within a country, but this can be greatly mitigated if the company sees this as part of a larger (national) marketing strategy, with positive spillovers to its activities in other locations.
- Building and maintaining the relationship with PSPs is highly time- and labor-intensive and can take years. CSISA-MI addressed this by having dedicated relationship managers who had regular (weekly if not more is often) interaction with their PSP counterparts in both the capital city and in the field.
- Relationship building with PSPs requires working with not only top management but with middle management wholesale/retail distribution. This can be a blind spot with the presumption that if senior leadership agrees to something, it can translate into facts on the ground. Similarly, private partnerships can often involve working with multiple divisions of a company, who often have differing objectives and strategies.
- CSISA-MI shows the advantages of starting with one to two partners with large market share and capital resources, thereby simplifying initial relationship management. At the same time, those partners were attracted by their quasi-monopoly status and potential for first-mover advantages. It also shows the need to introduce multiple PSPs once an initial track record of early adoption is established to diversify risks, create a wider and deeper market, increase competition, and signal to initial partners that other market actors now consider this a good business opportunity.

XI. LESSONS LEARNED FOR DONORS INTERESTED IN SCALING AGRICULTURAL INNOVATIONS

The CSISA-MI case generates multiple potential lessons for donors interested in scaling up agricultural innovations through commercial pathways.

1. Do not choose technologies or sectors ex-ante, based on research results and the size of the investment. It seems to work better to begin with multiple technologies that are field tested with farmers to tweak designs, identify what farmers find as their most productive uses, and ensure feasibility, profitability, desirability, and usability. This can be followed by narrowing down the number of technologies based on market feedback, and using the initial experience to profile what types of farmers, crops, and locations are likely to be early adopters.
2. Partner with private sector companies from the project start and insist on a largely co-equal relationship where partners share risk and investment. This involves having a strong business case to attract partners and to make credible insistence on significant financial co-investment.
3. Start with one to two key PSPs attracted by first-mover advantages to multiple markets to create proper signals and incentives and deepen and broaden the market. Criteria for choice of partners includes technical expertise and institutional commitment to the general sector and product line; large capital resources and an appetite for risk; a longer time horizon; and a solid and fairly dense distribution network. Branding and reputation of PSP seems to be important to adopters, including quality and, where appropriate, after-sales service.
4. It can take three to four years to identify the right technologies, early adopter characteristics, and crops and solidify relationship with PSPs.

5. Consciously adopt a flexible, adaptive management approach to overall strategy, work plans, and activities that is market driven, rather than simply targeting numbers of demonstrations, farmer participants, etc.
6. Supplement traditional M&E systems, which are largely geared to contract performance and accountability, with indicators that focus on marketing and sales data and measuring incentives. Monitoring systems such as the CSISA-MI MRM can be fed back into annual work plans.
7. Use price subsidies and co-funding of market and sales activities to improve the business case for the whole supply stream, and most importantly for early adopters. Price subsidies should be set depending on the price point of the technology relative to adopters' incomes and financial resources, and with an eye to substantially shortening the repayment period for the initial investment. Affordability and household budget studies can be helpful in this regard. Plan on phasing these out as critical mass is reached, depending on the speed of adoption. It seems that five years once final technologies and PSPs are selected is a reasonable expectation in the case of agricultural machinery. Subsidies can potentially be supplemented by public support.
8. Develop supplementary indicators of commercial sustainability for all key stakeholders (PSPs, LSPs, dealers, farmers) and monitoring data of uptake.
9. Because of institutional pressures for both numbers in short-term and long-term commercial scale/sustainability within many donor organizations, it is advisable to use a portfolio approach within a project or across projects to ensure that both objectives are reached.
10. The right contracting mechanism is critical. It must combine fixed high-level goals and some accountability to allow monitoring and feedback from the donor with substantial information for implementing partners on how to achieve them, including the choices of technologies, crops, partners, locations, and sequencing. Cooperative agreements seem to be the better format, allowing for the right mix of accountability and flexibility. Contracts are too inflexible, and grants have no accountability.
11. A flexible, adaptive approach needs to be built into all phases of a project: design, procurement, and implementation. Procurement can be a blind spot, as while the team that designs and implements the project from the donor side is often the same, the selection committee is different and may not be aligned with this approach. The field level leadership and staff on the donor side of a project need to be equally committed to a flexible, adaptive approach based on market feedback, which for many donor organizations is likely to require a change in internal culture, incentives, and staffing criteria.
12. Market facilitation skills such as marketing, sales, human-centered design, and working with PSPs are more important than technical skills or expertize. Where desirable to have a partnership between one or more organizations in implementation, the market facilitation organization should be the prime or in the lead, while research organizations should be limited to technical support.
13. Procurement mechanisms need to be explicit about tradeoffs between sustainability and achieving significant numbers in the early years of a project. Use of an S-curve approach requires devoting the first few years to experimentation, human-centered design, usability, and gauging market demand and reactions. Dedicating time at the onset of the project to systematically researching and testing potential machinery leads to more widespread and efficient adoption later and a grounded estimate of the size and nature of the potential market.
14. This case suggests that in many cases scaling will need to be done in two five-year phases. The first phase involves: 1) developing partnerships with the private and public sectors and identifying machines with agronomic potential, 2) test marketing and assessing market demand, 3) identifying and targeting early adopter farmers, and 4) iteratively improving designs. Then the next five years should be dedicated to scaling.
15. The suggestion to have an initial period of learning, trial and error, and feedback loops stands in contrast to political pressures on USAID-funded projects to demonstrate viability and impact quickly. Barring a change in these pressures, there are two potential solutions. One is to have projects where scaling is expected bundled into a larger project that has other activities that will

deliver quick wins and early results. Alternatively, the Mission needs to have other projects in its portfolio that are likely to produce large numbers quickly.

16. Scaling projects, especially those with a significant role for a research institution, need to have an experienced professional COP with management expertise, leadership skills, and donor relationship abilities consistent with an adaptive management approach. Research institutions do not always have such people on staff, nor do they have the internal human resources systems and salary scales in place that allow for recruiting and paying such people given current market rates. If research institutions are to lead or prime scaling and commercialization projects for their own technology, these obstacles will need to be addressed.
17. Scale the "Bangladesh Mission Model" and culture within USAID. The success of the Bangladesh Mission in establishing and scaling up the CSISA-MI project was due in large part to their intangible culture of collaboration with implementing partners, willingness to accept small numbers up front in favor of adaptive management and a market-oriented approach, and a diversified portfolio of projects. Forego immediate results in the interest of long-term market growth and benefit. This was similar to the approach used by the Senegal Mission in the case of scaling Sahel rice through the Projet Croissance Economique. The review team recommends spreading that culture throughout USAID through training and guidance documents for country Mission staff; it could be useful if there are affiliated tools that they can take back with them to their Missions. This would likely also require education and advocacy of USAID leadership and Congress on the long-term benefits, and developing modified M&E indicators consistent with an S-curve, commercialization approach.

ANNEX A: STAKEHOLDERS TARGETED FOR INTERVIEWS/FOCUS GROUPS

Stakeholder	Innovation Characteristics	Market System and Enabling Environment	Scaling Up and Market System Strengthening Strategies	Drivers and Pathways of Diffusion
Farmers	2	2	0	3
Retail Distributors	3	2	2	2
Wholesale Distributors	3	2	2	2
Field Sales Agents	2	0	2	3
Government Extension Agents	3	2	2	2
LSPs	4	2	2	1
Donor Project Field Staff	3	3	4	3
Local Ministry of Agriculture Officials	1	3	2	2
Producing Company Local Agents	3	1	3	2
Local Agricultural Financial institutions	1	3	2	1
National Level Producing Co. Management	4	3	3	2
National Ministry of Agriculture Officials	1	3	2	2
National Agricultural research Organizations	4	3	2	1
National level Donor project management	4	2	4	4
USAID staff	1	2	4	2
National Agricultural Financial institution management	1	2	2	2

ANNEX B: LIST OF INTERVIEWS

Interview	Attendees	Role
The Metal (Pvt.) Limited 04 April 2016, 3:45pm	Sadid Jamil	Managing Director
	Md. Humayun Kabir	AGM, Business Development
Unites States Agency for International Development (USAID) 05 April 2016, 10:00am	Matthew Curtis	
	Anar Khalilov	
	Mark Tagenfeld	
iDE Bangladesh 05 April 2016, 1:30pm	Mandud Hady	Intervention Manager, CSISA-MI
	Kevin Robbins	Deputy Project Manager, CSISA-MI
	Kafil Uddin	Intervention Manager, CSISA-MI
ACI Limited 05 April 2016, 5:00pm	Dr. F H Ansarey	Executive Director, Agribusiness
	Yeasir Ibne Ashab	Assistant Product Manager
Bangladesh Department of Agricultural Extension (DAE) 06 April 2016, 12:30pm	Sheikh Md. Nazim Uddin	Project Director, Enhancement of Crop Production Through Farm Mechanization Project-Phase II
Bangladesh Agricultural Development Corporation (BADC) 06 April 2016, 2:00pm	Md. Monirul Islam	Executive & Project Engineer, Surface Water Irrigation Rehabilitation in the Southern Delta Region of BD Project
Thengamara Mohila Sabuj Sangha (TMSS) 07 April 2016, 11:00am	Md. Sohrab Ali Khan	Director, Health Education & Microfinance (Operation)
	Munawar Reza Khan	Deputy Executive Director-3, Health, Education and Microfinance
	Md. Mahabubor Rahman	Director, Health, Education and Microfinance (Monitoring)
Rangpur Foundry Ltd. (RFL) 07 April 2016, 2:30pm	Sayed Joynul Abedin	Deputy General Manager (Operation)
	Chowdhury Fazle Akbar	Head of Marketing
	R.N. Paul	Director
International Maize and Wheat Improvement Center (CIMMYT) 07 April, 2016, 4:30pm	Timothy Krupnik, Ph.D.	Systems Agronomist
Bangladesh Agricultural Research Institute (BARI) 08 April 2016, 6:00pm	Md. Israil Hossain, Ph.D.	Chief Scientific Officer and Head, Farm Machinery & Postharvest Process Engineering Division
CIMMYT 20 April 2016, 12:30pm	Timothy Krupnik, Ph.D.	Systems Agronomist
iDE Bangladesh 20 April 2016, 3:00pm	Abrar Ahmad	
	Badrul	
	Mandud Hady	Intervention Manager, CSISA-MI
	Kevin Robbins	Deputy Project Manager, CSISA-MI
	Kafil Uddin	Intervention Manager, CSISA-MI

Interview	Attendees	Role
CIMMYT 21 April 2016, 8:00am	Bill Collis	Chief of Party, CSISA-MI Project
iDE Bangladesh 21 April 2016, 10:00am	Mandud Hady	Intervention Manager, CSISA-MI
	Kevin Robbins	Deputy Project Manager, CSISA-MI
	Kafil Uddin	Intervention Manager, CSISA-MI

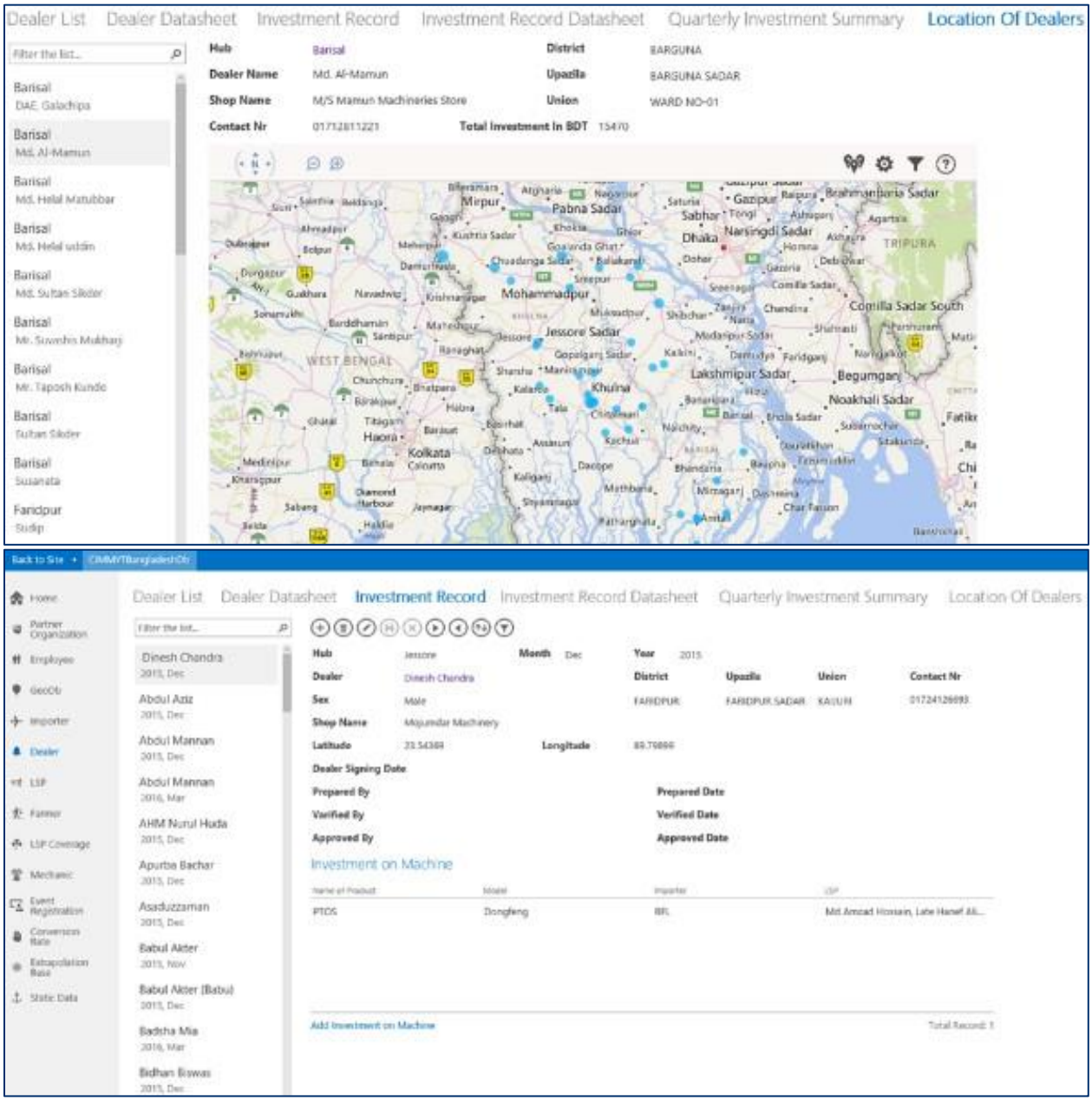
ANNEX C: M&E FOR SCALING UP THROUGH A MARKET APPROACH, THE MRM SYSTEM

In Year 2, iDE worked with an MRM consultant to design a custom MRM system using a variety of technologies described below. Whereas the M&E system tracks the project's progress against core FTF indicators, the MRM system informs project leadership about project implementation activities and changes within the market system. It tries to fuse the "s-curve" of scaling with DCED principles and real-time data to enable adaptive management. It has built-in feedback loops to enable project management to make better informed decisions about both short-term, tactical interventions and long-term, strategic interventions.

FIGURE 8: SAMPLE DASHBOARDS

Source: CSISA-MI Project Documentation

FIGURE 9: SAMPLE DATA VISUALIZATION



Source: CSISA-MI Project Documentation

CSISA-MI's MRM system includes:

- A **results chain** (Fig. II) which captures the project's market system theory of change, including activities, outputs, market triggers, market uptake, enterprise performance, sector growth, and poverty reduction. In addition to these vertical layers, the results chain includes horizontal layers associated with indicators of scale: adopt, adapt, expand, and respond (AAER).[41]

[41] For more on the Adopt-Adapt-Expand-Respond framework, see Daniel Nippard, Rob Hitchins , and David Elliott's 2014 briefing paper: "Adopt-Adapt-Expand-Respond: a framework for managing and measuring systemic change processes."

- An **intervention results assessment plan** (IRAP) that further explains each box of the results chain, including the what, how, who, and when of measurement.
- A **dashboard** (Fig. III) in Microsoft Excel that visualizes key progress indicators such as machines sales and project activities. These indicators can be filtered by geography, machine, project staff, or other variables. This dashboard is updated weekly with information that either the field team enters on tablets or data enumerators enter on laptops. Web forms allow all of this data to be aggregated in CSISA-MI's head offices.
- Records and analysis on **deep dives**, an HCD-oriented research technique used by project staff to better understand the desirability, feasibility, and viability of the target machines within the market. Questions include: Does the customer desire the product or service? Is the product or service feasible for companies to offer? Will the product or service be profitable/viable in the market? The Dhaka and field staff collaborate on analyzing the data resulting from the deep dives via Google Apps. The outcome is a report or a design deck identifying market system gaps and recommending interventions, which is accessible to the team via Google Drive.
- Annual **retrospective studies** which is a review of the recommendations made by the deep dives, conducted at the end of each project year. Rapid market appraisal techniques are used to gather information about dynamics within the market system, with the primary focus of seeing the market system from the perspective of the market actors, to understand how project activities affect them. Questions asked include: How did LSPs hear about the CSISA-MI targeted machines? Did the LSP need a loan to buy the machine? Were spare parts easy to find? The findings are published in a report that is available to the team via Google Drive.
- **Data visualization** (Fig. 4), currently provided through Microsoft Excel's Power Maps add-on, but next year through Salesforce and SharePoint – to better understand the relationships between variables such as crops, market actors, machine sales, and project activities.

Although the project is still fine-tuning its data capture, key questions that the CSISA-MI MRM system is trying to ask are provided below. In addition to this data, the project has identified a need to better track customer relationship management, and the health of private sector partnerships.

- Are staff doing the work we wanted them to do (based on our strategy)? Is the quality of that work up to par? What self-reflective lessons can staff learn to do that work better? Is that work having the desired effect in the market?
- Are private sector actors doing the work we expected them to do (based on JVAs, MOUs, incentives, facilitated linkages, etc.)? Is the quality of that work up to par? What self-reflective lessons can they learn to do that work better? Is that work having the desired effect in the market?
- Are other key actors (e.g., public sector and financial institutions) doing the work we expected them to do? Is the quality of that work up to par? What self-reflective lessons can they learn to do that work better? Is that work having the desired effect in the market?
- Where is the technology being adopted? By whom? Why? How? For what purpose?
- How effective are project activities and marketing in triggering adoption?
- What is the experience of the customer after adopting the technology?
- Is the capacity of PSPs increasing over time (e.g., Are they better at R&D? Are they better at importing? Are supply chains being managed better? Is retail ability increasing? Is after sales service getting better?)?
- Is the market functioning better? Are failures failing less? Are constraints relaxing? What are the key indicators of system health? Are those indicators improving?
- Are public attitudes about the target technology improving? Why?
- Is the brand value associated with those companies selling the target technology increasing? Why?

- What impact does target technology adoption have on incomes, poverty, livelihoods, well-being, resilience, inclusion, and/or empowerment (based on project priority objectives)?
- What is the progress along the S-curve? What is the progress against non-quantitative indicators of scale (stories of adaptation, copying-in, crowding-in, etc.)?

The implementation of the MRM at the end of Y2 was a significant turning point for the project. The ability to access data nearly real-time (some of the data is collected as frequently as weekly), and the ability to visualize it enabled more decisive strategies and management decisions. However, as of Y3 there are several learnings associated with the successful implementation of the MRM. First, the results chain and IRAP must be updated as project knowledge and strategy evolves in order to be useful, so reviews must be built into the team calendar. Second, the results chain must be harmonized with the detailed implementation plan in order to assess whether the implementation plan is achieving the desired results. Third, early implementation of an MRM is critical to the success of a market systems project, but tracking systems change (e.g., via copying-in and crowding-in phenomenon, etc.) is challenging for organizations and M&E staff accustomed to traditional methods, and may be deprioritized. Project management should consider adequately staffing the MRM system, or hiring outside consultants early on, to get the infusion of time, effort and knowledge necessary to establish and quickly evolve the system. Finally, although the onus of accurate and timely data collection is on the project field staff, they are often not the ones using the MRM and so do not personally experience the value of the data collection efforts. Investing in tablets to facilitate real-time data capture and otherwise eliminating barriers to fast and accurate data collection is essential to encouraging field staff to regularly capture high quality data. Additionally, CSISA-MI has been working with field staff to engage with the data and perform some of their own analysis, to encourage them to engage, defend, and criticize the data they are generating.

ANNEX D: MARKET SIZE CALCULATION METHOD

As the PTOS, AFP and reaper all are relatively new technology in Bangladesh, no existing research was found that accurately replicated the business models and contexts of the respective machines. The CSISA-MI team had to improvise and collect data from various sources and combine them to create a data context suitable for each machine to accurately reflect social, economic, and agronomic potential.

A two-step process was used in calculating the market sizes for PTOS, reaper and AFP. The first step was to collect Upazila wise quantitative data on actual hectare coverage of different suitable crops for the three types of machines. Data sets were gathered from CIMMYT's Map Explorer, Bangladesh Bureau of Statistics (BBS), Bangladesh Integrated Household Survey and the Department of Fisheries. Data sets were organized to reflect each machine's business model.

The second step involved the iDE field team to counter or validate the data sets to accurately reflect the context of the respective areas. The rationale of using a subjective reasoning was to take into consideration the unique agronomic conditions and practices of each Upazila and how the three machines were used in that context.

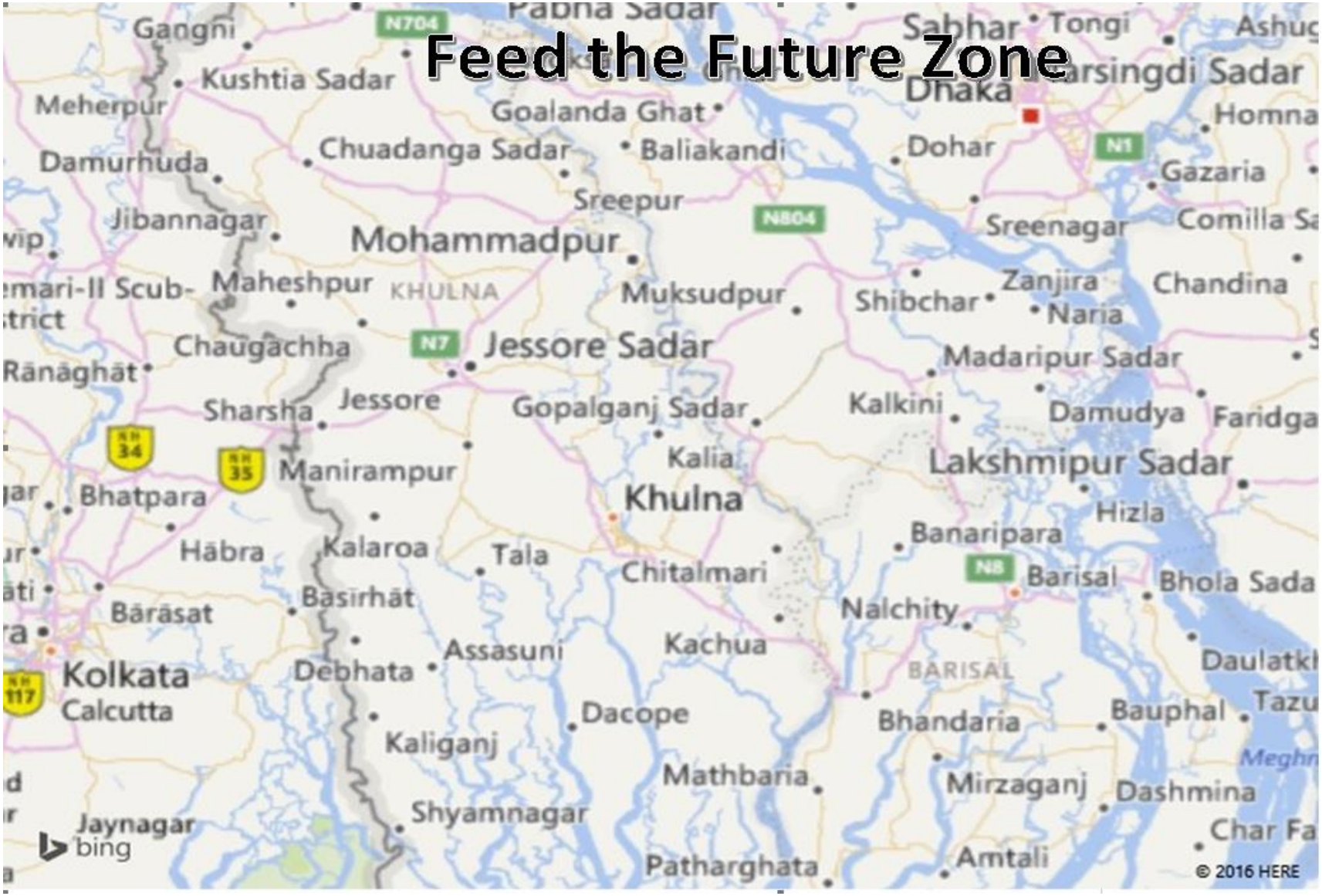
The refined hectare coverage of suitable crops represented the ceiling amount that a machine could service in a particular area. To convert this serviceable area into the maximum number of machines in the market, the team took an average number of hectares covered by each machine based on three years of hectare coverage data provided by CIMMYT:

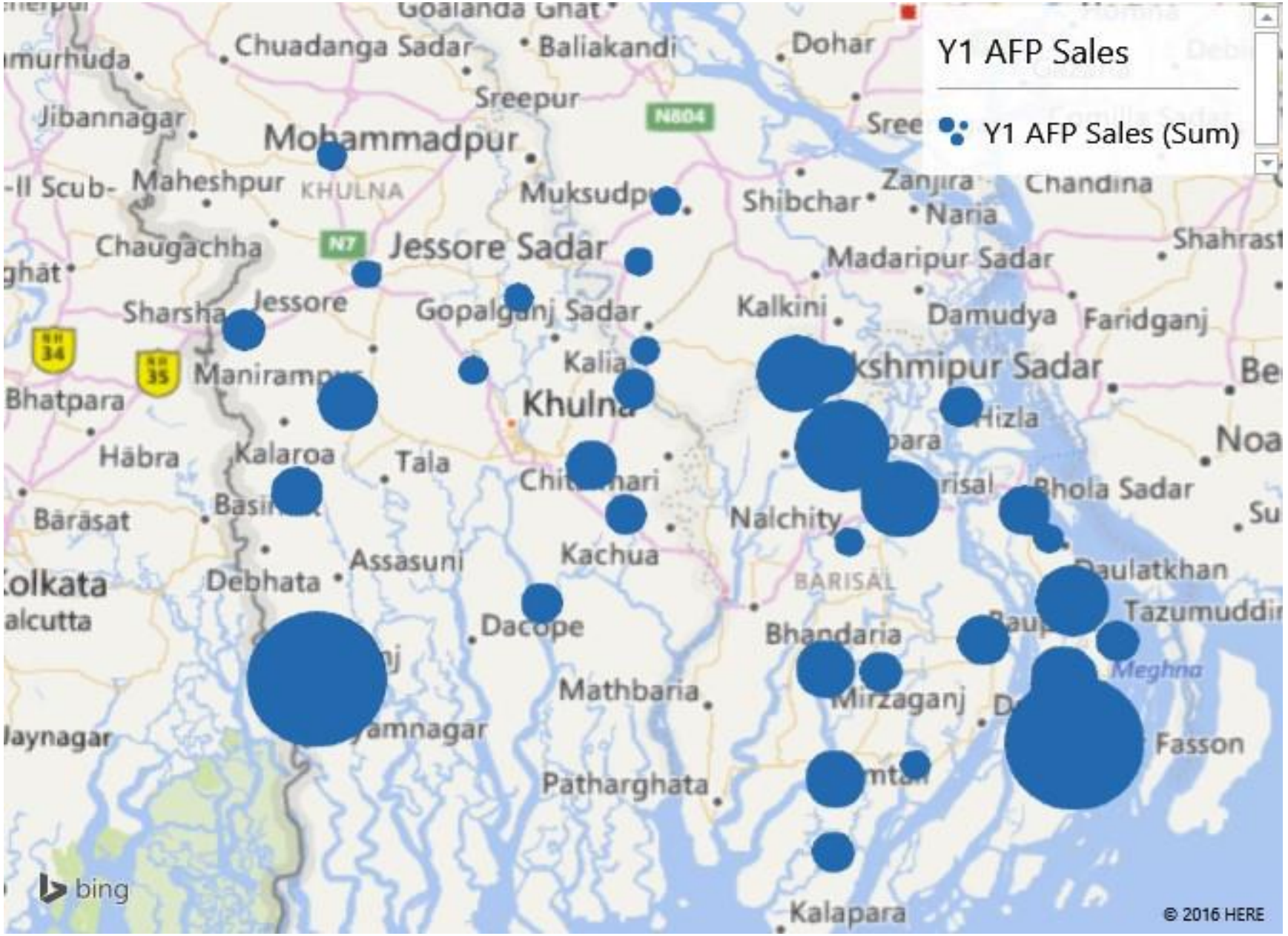
- AFP: 19 hectares per machine per year for Boro, 5 hectares per machine per year for Gher
- PTOS: 22 hectares per machine per year for all crops
- Reaper: 22 hectares per machine per year for all crops

The following table highlights the factors considered for each machine and their respective sources:

	Factors	Source
AFP	Surface Water	CIMMYT Map Explorer
	Canal	BBS
	Boro	CIMMYT Map Explorer and iDE Field Team
	Gher	Department of Fisheries
	Watermelon	BBS
	3 meter head	IDE Field Team
	Water salinity	IDE Field Team
	Soil salinity	IDE Field Team
PTOS	Soil hardness and type	iDE Field Team
	Rabi crops: onion, wheat, mustard, mungbean, lentil	BBS
	Kharif crops: jute	BBS
	Number of power tillers	Good indicator of early adoption but not of market size
Reaper	Wheat	BBS
	Boro	BBS
	Aman	BBS
	Water level during reaping (high vs low land)	IDE Field Team
	Bichali practice	IDE Field Team

ANNEX E: SPATIAL ADOPTION PATTERNS




Y1 AFP Sales
Y1 AFP Sales (Sum)
Chuadanga Sadar
Baliakandi
Dohar
Sreepur
Jibannagar
Mohammadpur
Maheshpur
KHULNA
Muksudpur
Shibchar
Zanjira
Chandina
Naria
Chaugachha
Jessore Sadar
Madaripur Sadar
Jessore
Sharsha
Gopalganj Sadar
Kalkini
Damudya
Faridganj
Bhatpara
Khulna
Hizla
Habra
Kalaroa
Tala
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Barasat
Nalchity
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Fasson
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Kalapara
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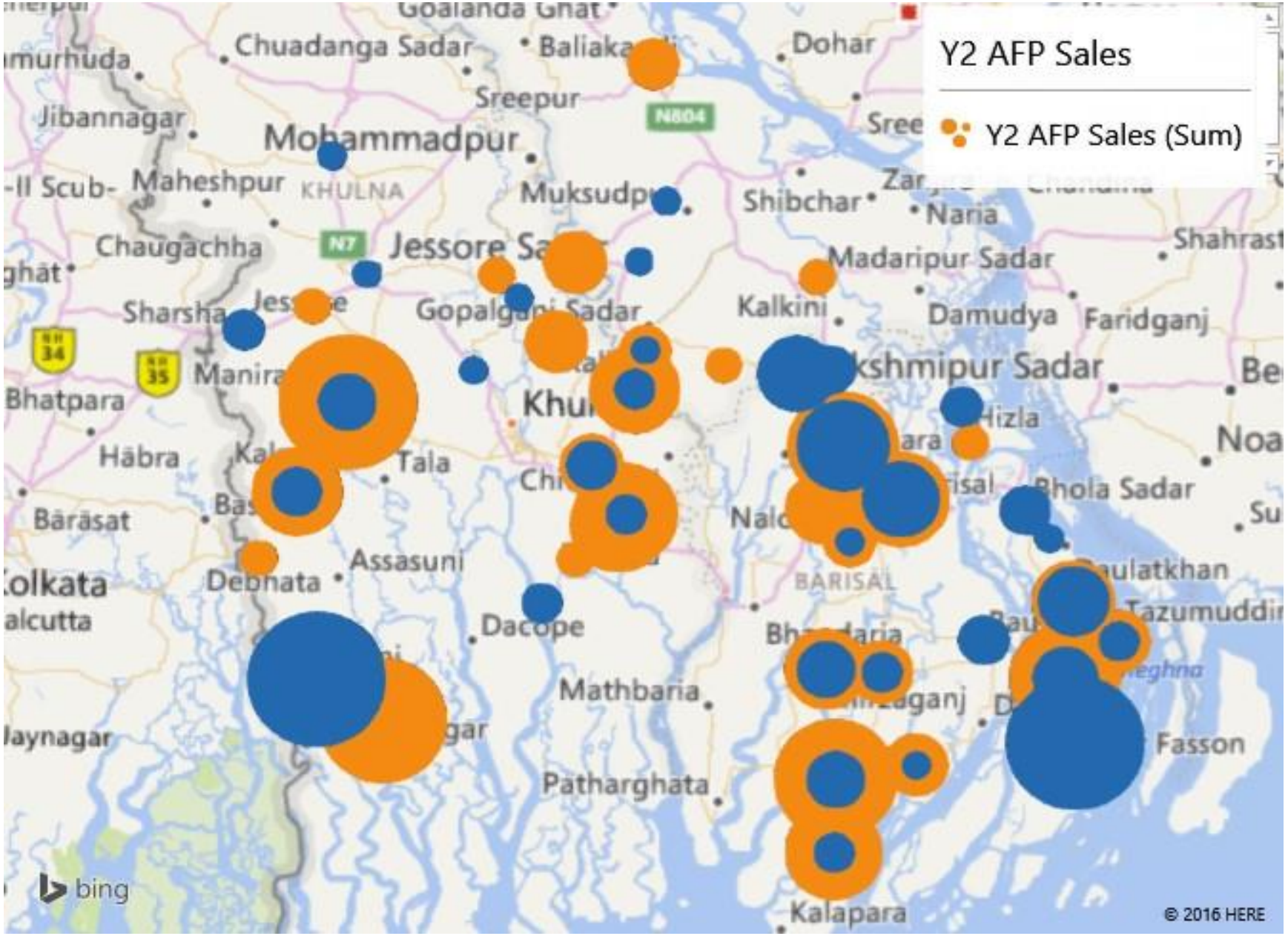
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Y2 AFP Sales (Sum)
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Mohammadpur
Maheshpur
KHULNA
Jessore
Chaugachha
Sharsha
Manirampur
Bhatpara
Habra
Tala
Barasat
Assasuni
Debnata
Dacope
Mathbaria
Patharghata
Kalapara
Dohar
Shibchar
Naria
Madaripur Sadar
Kalkini
Damudya
Faridganj
Hizla
Bhola Sadar
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Fasson
Kolkata
Jaynagar
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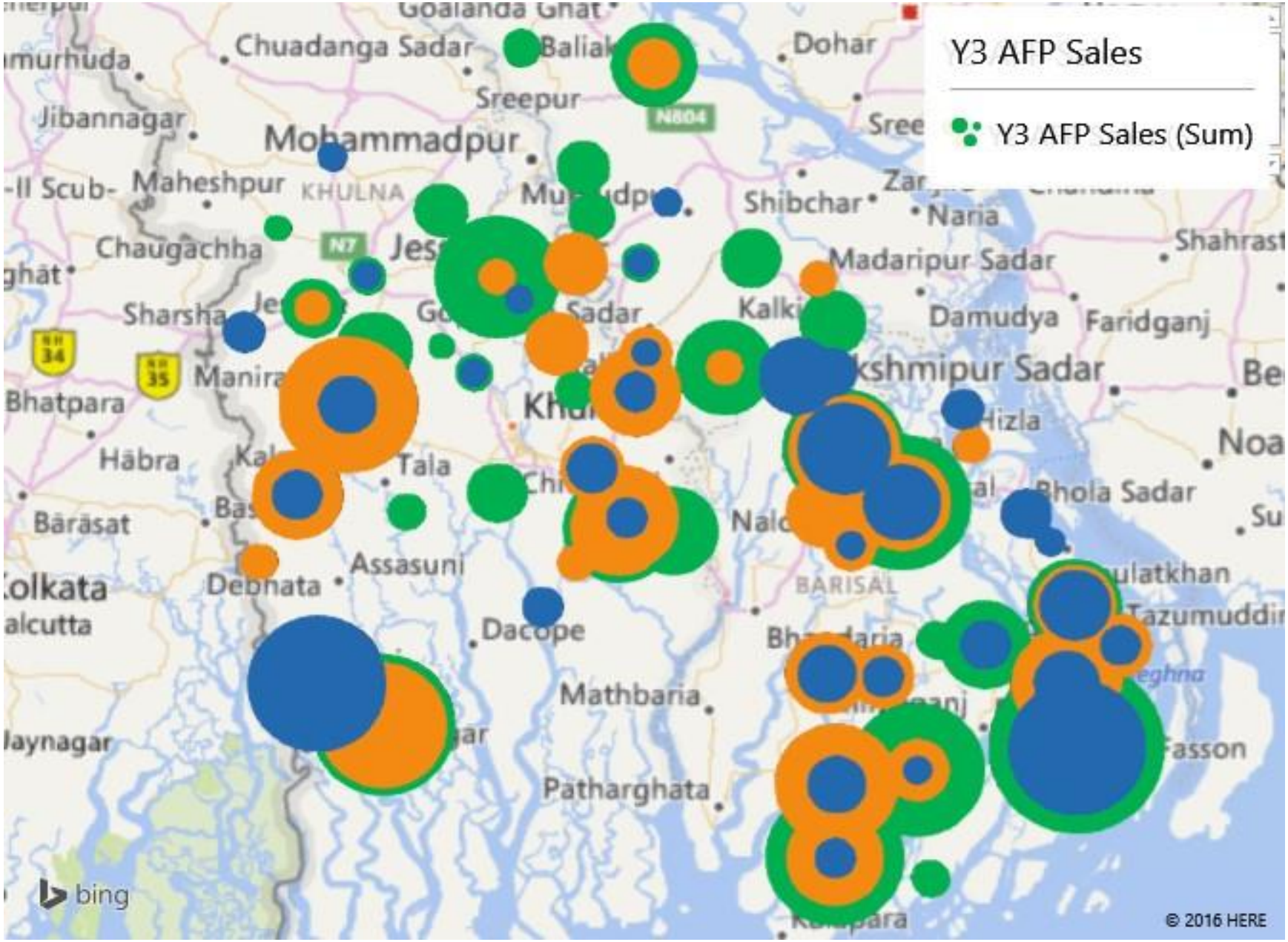
Y3 AFP Sales
Y3 AFP Sales (Sum)
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Sreepur
Dohar
Jibannagar
Mohammadpur
Maheshpur
KHULNA
Shibchar
Naria
Chaugachha
Madaripur Sadar
Sharsha
Sadar
Damudya
Faridganj
Bhatpara
Habra
Tala
Hizla
Bhola Sadar
Barasat
Assasuni
Debnata
BARISAL
Dacope
Mathbaria
Patharghata
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Y1 PTOS Sales
Y1 PTOS Sales
Pabna Sadar
Gangni
Kushtia Sadar
Meherpur
Damurhuda
Chuadanga
Ghior
Sabha
Dhaka
Dohar
Gazaria
Jibannagar
Mohammadpur
Sreenagar
Comilla
Maheshpur
KHULNA
Zanjira
Chandina
Shibchar
Naria
Chaugachha
Jessore Sadar
Madaripur Sadar
Rānāghāt
Sharsha
Gopalganj Sadar
Kalkini
Damudya
Faridga
Manirampur
Kalia
Lakshmipur Sadar
Bhatpara
Khulna
Hizla
Banaripara
Hābra
Kalaroa
Tala
Chitalmari
Barisal
Bhola Sada
Bārāsat
Basirhāt
Nalchity
Assasuni
Kachua
Kolkata
Calcutta
Debhata
BARISAL
Dacope
Bhandaria
Bauphal
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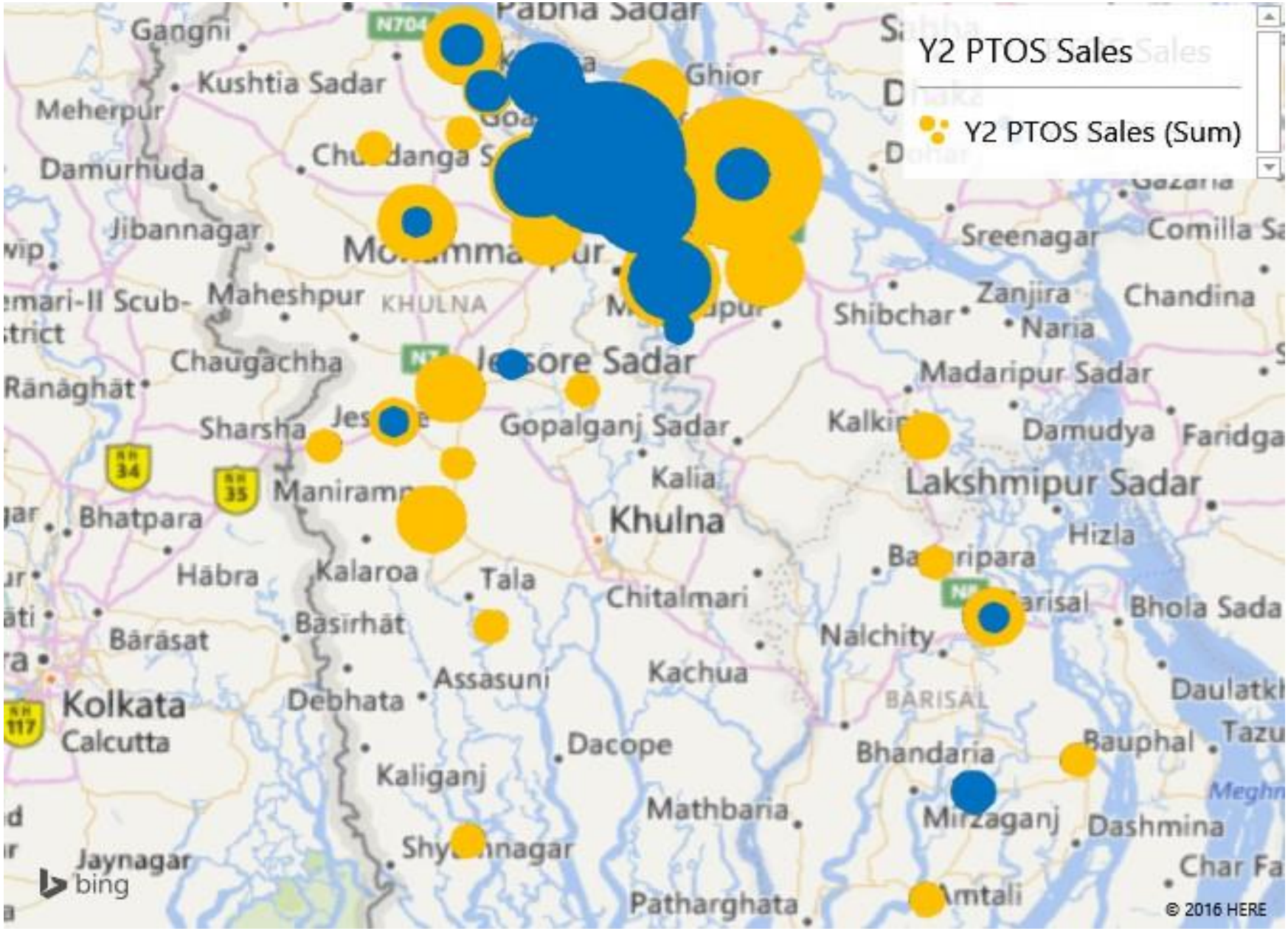
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Gangni
Kushtia Sadar
Meherpur
Ghior
Damurhuda
Jibannagar
Sreenagar
Comilla
Maheshpur
KHULNA
Zanjira
Chandina
Shibchar
Naria
Chaugachha
Jessore Sadar
Madaripur Sadar
Rānāghāt
Sharsha
Gopalganj Sadar
Damudya
Faridga
Kalia
Lakshmipur Sadar
Khulna
Bhatpara
Hizla
Hābra
Kalaroa
Tala
Chitalmari
Bhola
Bārāsat
Bāsirhāt
Nalchity
Assasuni
Kachua
Kolkata
Calcutta
Debhata
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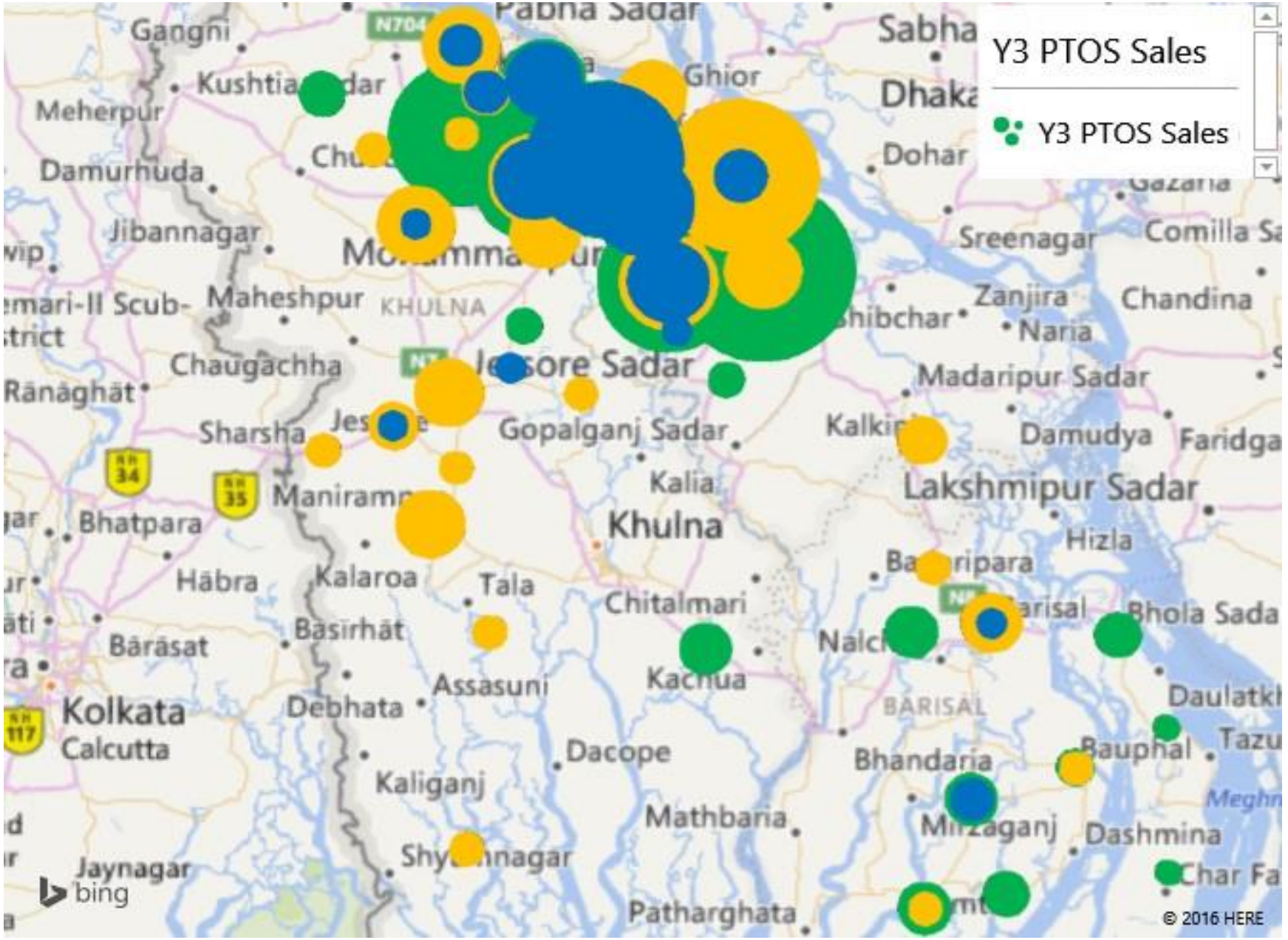
Y3 PTOS Sales
Y3 PTOS Sales
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Gangni
Kushtia
Meherpur
Damurhuda
Ghior
Dhaka
Dohar
Jibannagar
Sreenagar
Comilla
Maheshpur
KHULNA
Zanjira
Chandina
Naria
Chaugachha
Jessore Sadar
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Rānāghāt
Sharsha
Gopalganj Sadar
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Faridga
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Bhola Sada
Bārāsat
Bāsirhāt
Nalch
Assasuni
Kachua
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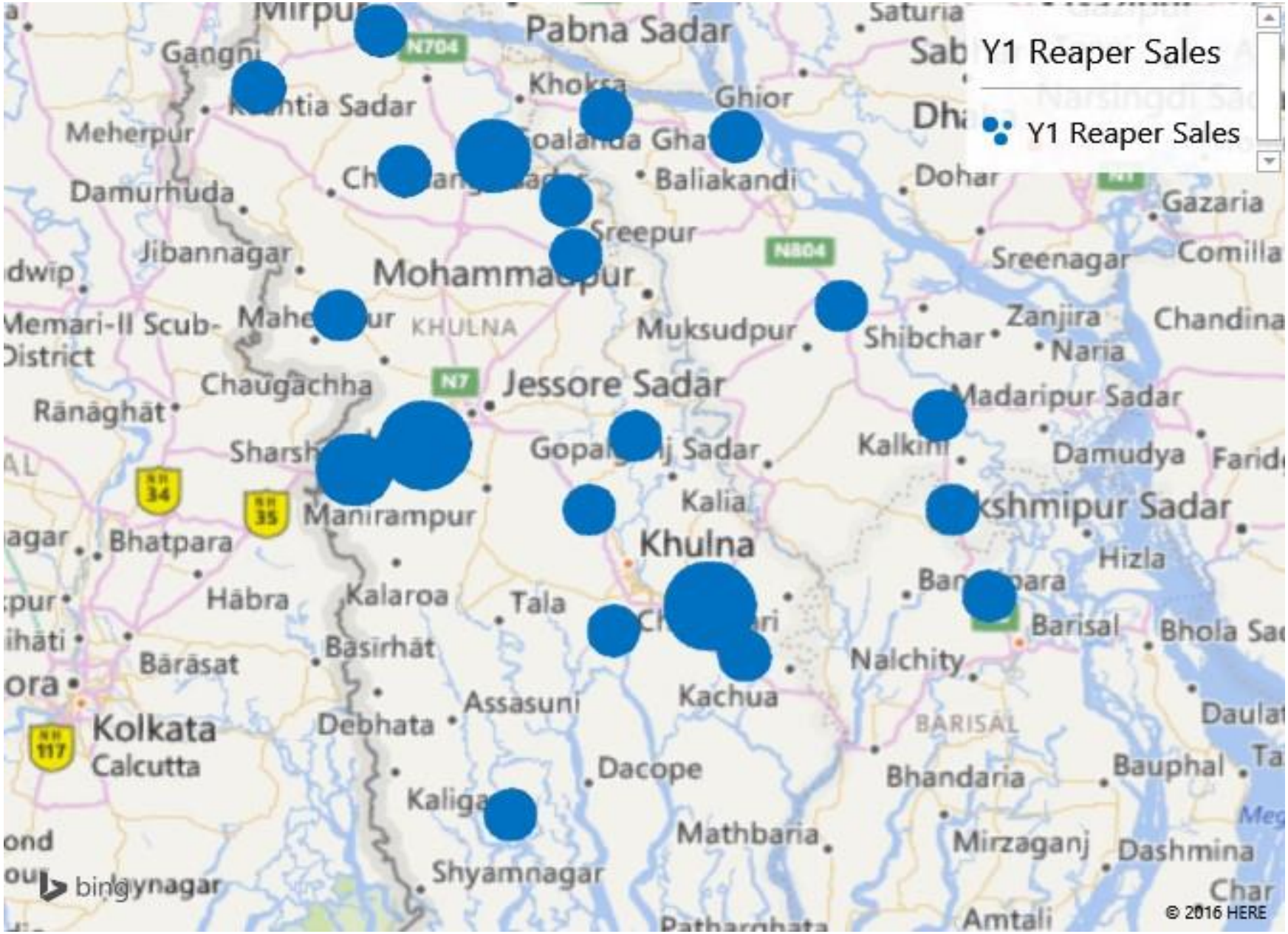
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Baliakandi
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Damurhuda
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Mohammadpur
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Muksudpur
Shibchar
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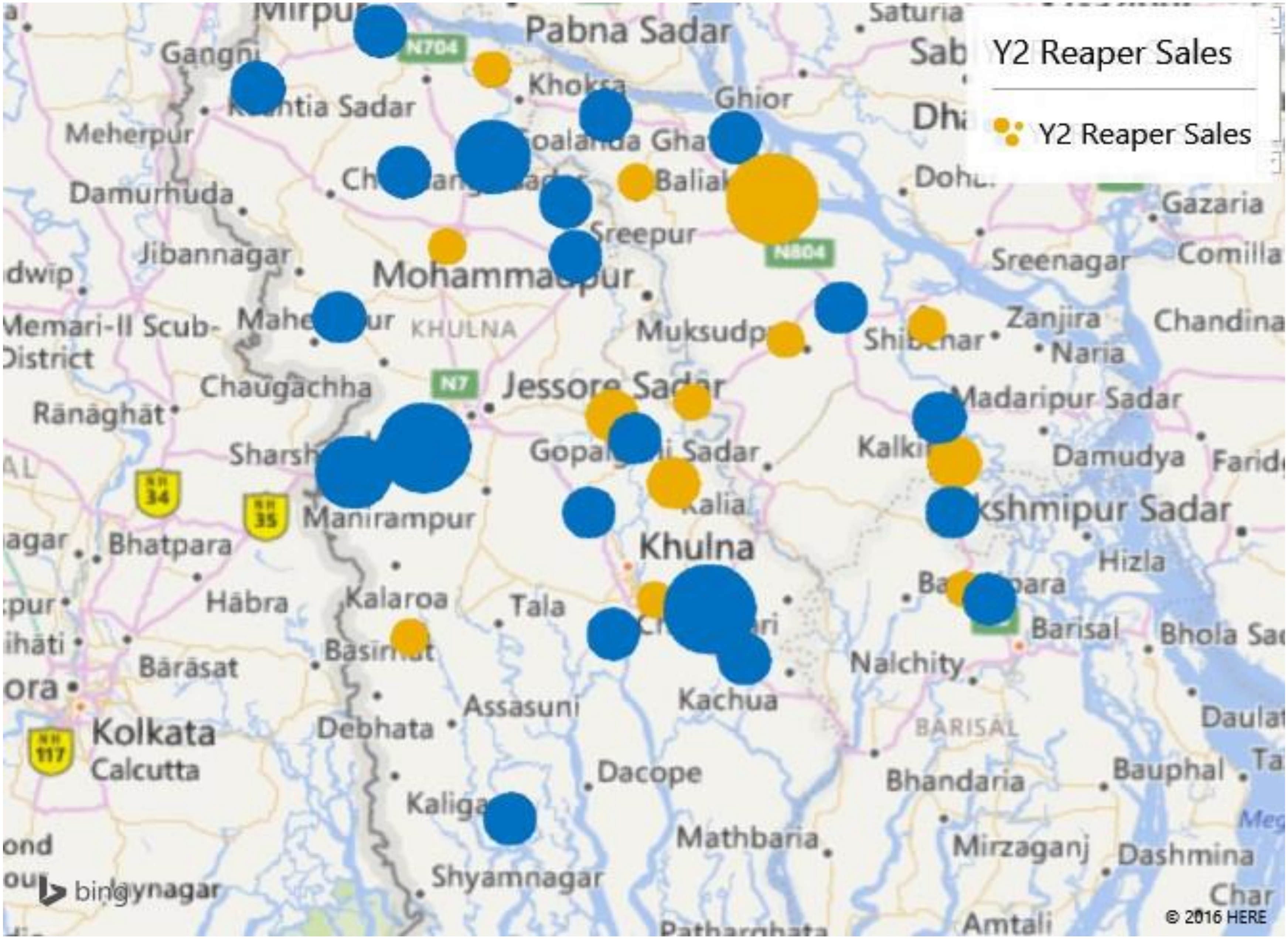
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Comilla
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Ranaghat
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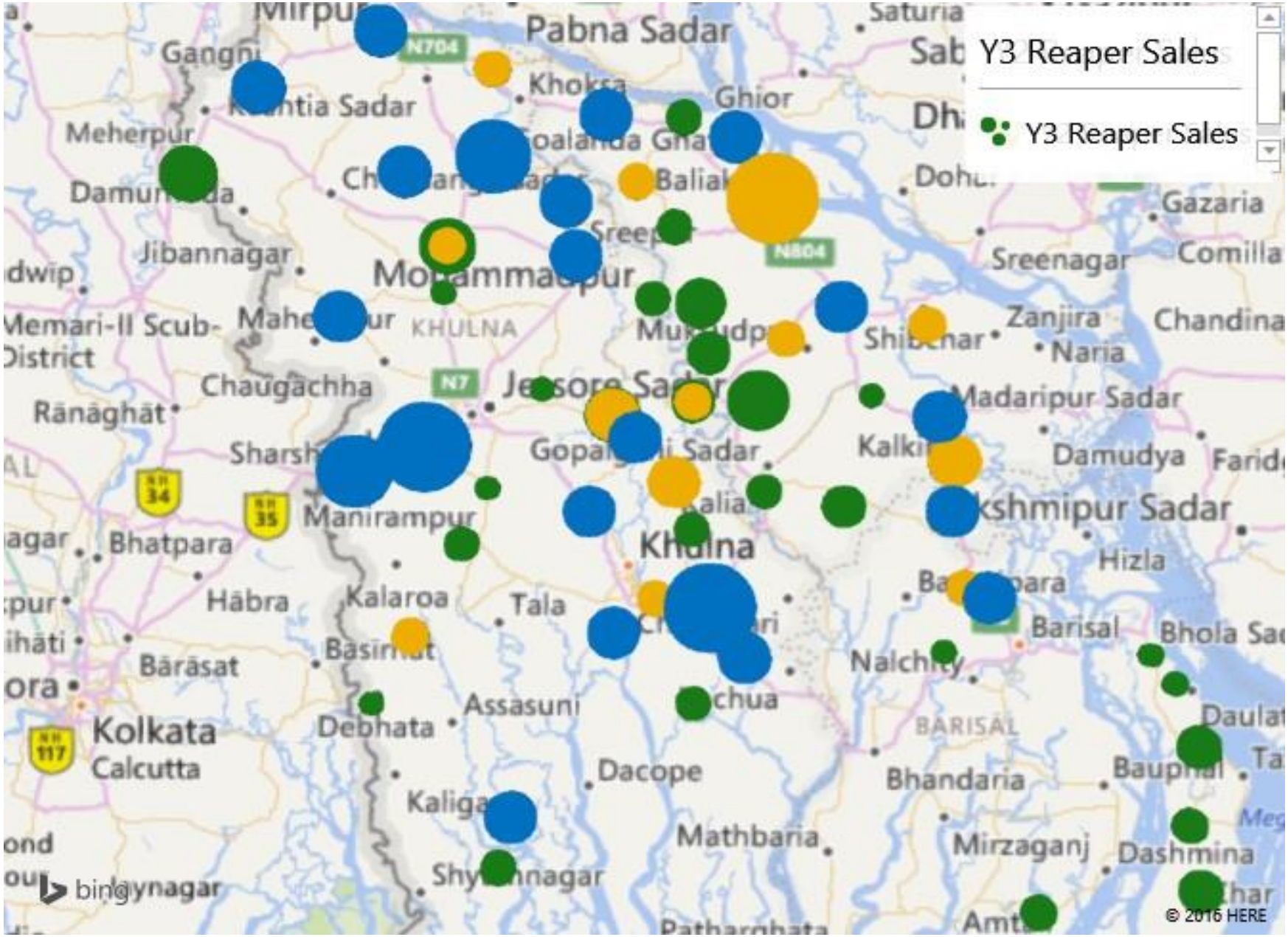
Y3 Reaper Sales
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Manirampur
Bhatpara
Hābra
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Khulna
Bārāsat
Kolkata
Calcutta
Assasuni
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