CSISA

Cereal Systems Initiative for South Asia Phase II

Project Report (2012-2015)

Submitted by

International Maize and Wheat Improvement Center (CIMMYT)

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CIMMYT International Maize and Wheat Improvement Center

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ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

CEREAL SYSTEMS INITIATIVE FOR SOUTH ASIA (CSISA) PHASE II

Project Report

2012-2015

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Cereal Systems Initiative for South Asia Phase II

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The Cereal Systems Initiative for South Asia (CSISA) is a research-for-development partnership implemented jointly by CGIAR members—the International Maize and Wheat Improvement Center (CIMMYT), the International Food Policy Research Institute (IFPRI), the International Livestock Research Institute (ILRI), the International Rice Research Institute (IRRI), and World Fish, in close partnership with public and private sector organizations across South Asia. CSISA is funded by the United States Agency for International Development (USAID) and the Bill and Melinda Gates Foundation. CSISA is an integral part of several CGIAR Research Programs (CRPs), connecting and integrating their work in South Asia. These CRPs include: CRP 2: Policies and markets; CRP 3.1: WHEAT; CRP 3.2: MAIZE; CRP 3.3: GRiSP; and CRP 3.7: Livestock and fish. CSISA also has interactions in South Asia with CRPs 1.1: Dryland systems; 1.3: Coastal and aquatic systems; 4: Nutrition and health; 5: Water and land; and 7: Climate change.

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Andrew McDonald
Project Leader, CSISA Phase II

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Acronyms and Abbreviations

Acronym	Full Name of Acronym
ACI	Advanced Chemical Industries
AFP	Axial flow pump
AFT	Axial flow thresher
AWD	Alternate wetting and drying
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
CSISA-MI	CSISA Mechanization and Irrigation project
DOA	Department of Agriculture
DSR	Direct-seeded rice
EIGP	Eastern Indo-Gangetic Plains
EUP	Eastern Uttar Pradesh
fb	Followed by
GAP	Good Agricultural Practices
GWP	Global Warming Potential
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
MTNPR	Machine-transplanted non-puddled rice
NARES	National agriculture research and extension systems
PTOS	Power-tiller Operated Seeder
PTR	Puddled transplanted rice
RCM	Rice Crop Manager
RFL	Rangpur Foundry Limited
RWCM	Rice–Wheat Crop Manager
SHG	Self-help group
SP	Service provider
USAID	United States Agency for International Development
ZT	Zero tillage

Highlights from Phase II

Overview & Achievements

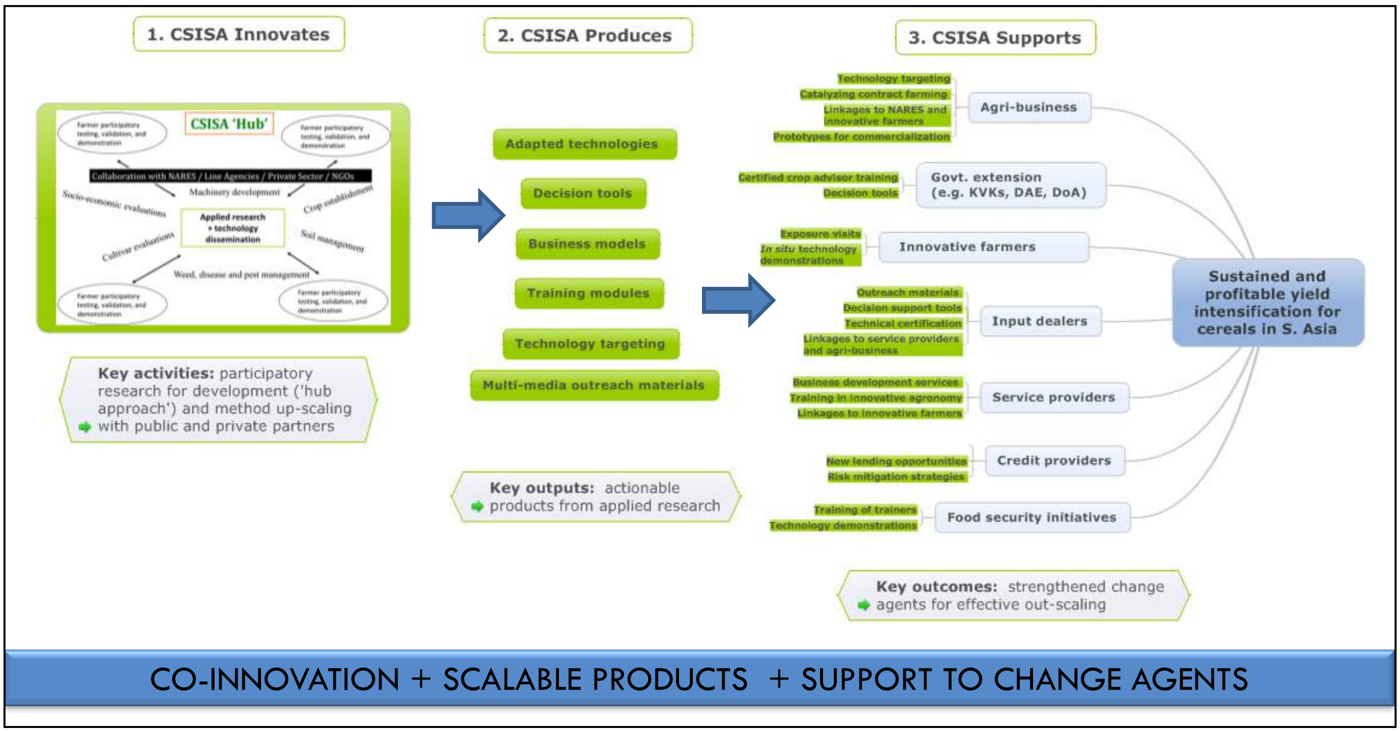
In recent years, gains in cereal productivity in South Asia have slowed markedly. Issues of resource degradation, declining labor availability and climate variability also pose steep challenges for achieving sustainably intensified cereal-based systems that can improve food security and rural livelihoods. To address these challenges, the Cereal Systems Initiative for South Asia (CSISA) was established in 2009 to catalyze durable change at scale in South Asia's cereal systems. CSISA pursues research and innovation system interventions to accelerate the adoption of sustainable intensification technologies.

Operating in rural innovation hubs in Bangladesh, India and Nepal, CSISA involves partnerships with the public, civil society and private sectors for the development and inclusive deployment of improved cropping systems, resource-conserving management technologies, new cereal varieties and hybrids, livestock feeding strategies and feed value chains, progressive policies and strengthened markets. As a science-driven and impacts-oriented initiative, CSISA resides at the intersection of a diverse set of partners, occupying the 'messy middle' where research meets development. CSISA is built on the premise that transformative development typically requires not one change, but the orchestration of many.

CSISA Phase II is composed of six linked objectives:

1. Catalyzing widespread dissemination of production and post-harvest technologies to increase cereal productivity, resource use efficiency and income
2. Process-based research into crop and resource management practices for future cereal-based systems
3. High-yielding, heat- and water-stress tolerant rice varieties for current and future cereal and mixed crop–livestock systems
4. High-yielding, heat- and water-stress tolerant, and disease-resistant wheat varieties for current and future cereal and mixed crop–livestock systems
5. Improved policies and institutions for inclusive agricultural growth
6. Project management, data management, M&E and communications.

The operational model deployed by CSISA in Phase II (2012 – 2015) to reach scale with adapted and targeted interventions emphasized 1) co-innovation with farmers and value chain actors, 2) production of durable products and insights, and 3) the targeted sharing of those products with 'change agent' intermediaries that in turn reach large numbers of farmers:



This operational model has permitted CSISA to exceed our impact targets for Phase II while continuing to develop science-based innovations. In aggregate, approximately 2.2 million households are utilizing new technologies and crop varieties as a result of CSISA's scaling partnerships in Phase II:

INTERVENTION	ADOPTING HOUSHOLDS	SCALING PATHWAYS
Timely crop establishment	702,227	Revision of state recommendations
Stress-tolerant and high-yield cultivars	1,166,845	Seed system strengthening
Resource-conserving crop establishment and land preparation	197,353	Service provision
Safe and effective weed control	175,912	Agro-dealers
TOTAL	**2,242,338**	

Highlights by Objective (through Nov 2015):

Objective 1 & 2

- **Building a service economy for SI:** CSISA has supported the emergence of a nascent but robust service economy for SI technologies with over 1,900 SPs now active in Bihar and EUP alone.
- **Accelerating spread of mechanized SI technologies**: As a result of CSISA's collaboration with the national agriculture research and extension systems (NARES) and private sector entrepreneurs, more than 37,000 hectares zero tillage wheat in 2014–15 across CSISA's working districts in Bihar and EUP through low-cost access to capital-intensive machinery through service providers. Area under ZT increased by more than 68% over 2013-14.
- **Achieving productivity and profitability gains at scale:** CSISA's on-farm surveys document average yield gains of 498 kg/ha and net revenue increases of $110/ha with ZT wheat. In aggregate, this translates to an estimated gain of 18,445 t of additional wheat production and an on-farm profitability increase of more than $4.07 m USD on an annual basis.
- **Increasing resilience to climate extremes:** Timely planting of winter crops ensures that high temperatures in the spring do not reduce yields. In partnership with the Bihar State Department of Agriculture, the area under early sowing of wheat in 2014–15 increased by an estimated 37% to exceed 62,000 hectares.
- **Strengthening input systems**: With support from CSISA, sales of hybrid rice in Bihar increased by 500 t in 2015, with an estimated area expansion of 33,000 hectares.
- **Reaching a critical mass of 'first innovators' in new regions:** Awareness and utilization of SI technologies was extremely low in Odisha when CSISA started activities in 2012. The spread of MTR, DSR, line sowing and diversification has resulted in an area of 4,460 ha transitioning to SI technologies in last year of Phase II.
- **Compelling private sector investment:** CSISA's approach to achieving and sustaining impact with farmers through markets and public-private partnerships is paying off. From a base of zero, private sector reaper sales for the 2-wheel tractor exceeded 100 units in Nepal during the reporting period with importers adding new stocks of more than 400 units in advance of 2015-16 Rabi season. In Bangladesh through the CSISA-MI project, Rangpur Foundry Ltd. imported 446 seed and fertilizer drills with technical and market development assistance from CSISA.
- **Meeting our goals:** As the USAID-Bangladesh funded 'CSISA-BD' (2010 – 2015) investment draws to a close, more than 215,000 farmers have benefited from core programming on sustainable intensification technologies with a further million farmers receiving new stress tolerant rice varieties.
- **Sustaining a legacy of impact**: In CSISA's transition hubs in NW and Southern India, government partners and entrepreneurs continue the good work that CSISA and predecessor investments such as the Rice-Wheat Consortium initiated. For example, service providers in Haryana have laser leveled an estimated 162,000 ha and there are approximately 2,850 levelling machines deployed by service providers across the state. In Thirvarur District, Tamil Nadu, more than 27,000 acres of directly sown rice (DSR) was planted using seed drill sowing in last

samba season.

- **Generating new innovations**: Most of the pressing challenges confronting agriculture in South Asia cannot be addressed with single technologies, and often require integrated approaches and systems-level interventions. CSISA's work on combining crop genetic advances with conservation agriculture and improved water management in the stress-prone eastern IGP shows significant promise for stabilizing wheat yields under a shrinking window of opportunity for winter cropping due to climate change. Moreover, variable rainfall patterns and monsoon failures have become the norm in South Asia. Field and simulation studies demonstrate the importance of planting short and medium duration rice cultivars to maintain systems productivity, especially when rice planting is delayed due to late onset of the monsoon rains.

Objective 3

- **Rice breeding for new agronomy:** During the wet season 2014, 36 entries in early, 40 entries each in medium early and medium duration were evaluated under machine sown dry DSR conditions at seven locations in India. The mean grain yield advantage of the top five entries over the best check in respective maturity groups ranged from 10–20% over Sahabhagidhan (4.9 t/ha) for early, 14-19% over MTU1010 (5.6 t/ha) for medium, and 10-15% over NDR 359 (5.4 t/ha) for long-duration cultivars.

Objective 4

- **Release and scaling of new wheat varieties**: made significant progress by releasing 17 new wheat varieties that have superior yield potential and are well-buffered against the vagaries of climate change, have greater resistance to biotic stresses, are fully adaptable to the CA practices and have consumer preferred end-use qualities. These varieties showed yield advantage of 5–14% and two-thirds of the varieties were shorter in duration than prevalent cultivars enabling their higher suitability for intensive cropping systems. Formal sector seed production figures indicated that CSISA-bred wheat lines account for 18% of sales in India, 24% in Nepal and 34% in Bangladesh.

Objective 5

- **Reforming extension**: CIMMYT and IFPRI organized a learning event on "Strengthening Agricultural Research, Extension, and Input Markets in South Asia: Evidence from Regional and Global Practice," in Washington, DC, June 8-9, 2015. Key partners from the agricultural research and extension systems of Bangladesh, India, and Nepal participated in this event as an add-on to their participation in the global MEAS symposium held during the prior week. The event was an opportunity for participants to explore extension system reforms in a new and critical light, and have established the foundation for more strategic and action-oriented partnerships with CSISA in Phase III.
- **Reaching consensus on investment priorities**: CIMMYT and IFPRI helped coordinate and intellectually contributed to the National Seed Summit convened by the Nepal Ministry of Agricultural Development, Kathmandu, September 14-15. The event was an important pan-stakeholder event designed to translate Nepal's new Seed Vision 2020 into implementation, with emphasis placed on reforms to regulations governing variety registration, quality control, and private sector investment. This event has set the stage for a forthcoming investment in Nepal's seed systems by USAID that will be led by CIMMYT and functionally linked to CSISA.

Progress by Crop, Geography & Theme

WHEAT

Due to changing dietary preferences and a decline in the area cropped to rice, the importance of wheat as a food security and income-generating crop has significantly increased since the early 1990s in places like Bihar in Eastern India. At present, it is the second most important source of caloric intake in South Asia and the gap with rice is closing. Despite growing consumer demand, areas like Bihar remain net importers of wheat in most years (868,000 MT in 2010-11). Fortunately, opportunities for intensification are much higher in the Eastern Indo-Gangetic Plains (EIGP) where CSISA's work is focused than in the Central and Western IGP. However, the more extreme climate and patchy nature of critical infrastructure to support production and procurement present significant roadblocks to intensification.

Across CSISA's working domain, wheat productivity is constrained by abiotic and biotic stresses, low or imprecise rates of input use, and slow varietal turnover. Yields are further limited by terminal heat – temperatures above 35 C (95°) during the grain-filling stage. CSISA research has shown that wheat yield growth rates, as well as overall productivity, can be increased if farmers adopt a few complementary innovative agronomic practices and technologies that together provide resilience against terminal heat and improve input use efficiencies.

India

Bihar and Eastern Uttar Pradesh (EUP) possess tremendous potential for improving wheat productivity despite historically low yields and a variety of productivity constraints. In 2008–09, wheat yields in CSISA's hub domains averaged around 2 t/ha in Bihar to 2.6 t/ha in EUP. By 2015, in our core working areas the initiative helped farmers achieve yields of 4.89 t/ha in Bihar and 4.6 t/ha in EUP. The primary mechanisms for achieving these yield increases are described below.

Early Wheat Sowing and Zero Tillage

CSISA's on-farm research documents dramatic improvements when wheat planting is advanced to early November. In Bihar, average yields of 4.71 t/ha were harvested from crops sown during the first two weeks of November, whereas 2.86 t/ha was achieved when wheat was sown in the last two weeks of December. Shifting from the first half of December to the second half of November increased average yields by nearly 1 MT per hectare.

Zero tillage (ZT) is the most crucial factor in the success of early wheat sowing. It allows farmers to seed wheat immediately after rice is harvested, cutting costs, saving time and using residual moisture effectively. In CSISA's evaluation trials, ZT wheat consistently outperformed conventional tillage wheat, achieving yields of 4.89 t/ha when planted in the first two weeks of November, compared to 4.42 t/ha under conventional tillage. To assess the performance of zero tillage in farmers' fields in India, CSISA researchers conducted a survey among 1,000 randomly selected wheat farmers who comprised 400 ZT users and 600 non-users and were spread across 40 randomly selected villages in six districts of Bihar. Based on the survey, a yield increase of 498 kg per hectare (19%) was estimated for ZT wheat as compared to conventional-tillage wheat, and a total economic gain from yield increase and cost savings of US$ 110 per hectare, constituting a 6% increase in total annual income for the average wheat farming household. In a scenario of full ZT wheat adoption in Bihar, a 19% yield increase would translate into a production increase of 950,000 metric tons, exceeding total wheat imports into Bihar and suggesting that broad-scale adoption of ZT technology could play a major role in making Bihar self-sufficient in wheat.

Before CSISA's efforts, the State Departments of Agriculture (DoA) in UP and Bihar had long-standing guidance that the proper time to sow wheat was after November 15, when farmers can "see their breath in winter." Planting after November 15 leaves crops increasingly vulnerable to terminal heat in March. To encourage the state extension system to revisit the official recommendations, CSISA spread the word about the benefits of early wheat sowing by sharing quantitative results from on-farm trials across years and locations. Due to size of the sample and response consistency, we captured the attention and imagination of our public sector partners.

Starting with the 2011–12 wheat season, CSISA attended the DOA's pre-season district-level workshops where field officers, extension personnel and grassroots workers decided which programs to implement. CSISA shared data on the benefits of early wheat sowing as well as information about zero tillage as a means to get the wheat crop sown earlier. Early wheat sowing and zero tillage became CSISA's 'one–two punch' against stagnated wheat yields in the Eastern Indo-Gangetic Plains.

In collaboration with the KVKs and other partners, CSISA conducted on-farm demonstrations and joint field operations so that 'ownership' of the findings was broadened to the national system. CSISA also worked with other partners at differing points along the agricultural research, extension and production chain, including with the Indian Council of Agriculture Research, the Agriculture Technology Management Agencies, private sector companies and NGOs, to disseminate mounting evidence that early wheat sowing, facilitated by zero tillage, could address the problems of terminal heat and yield stagnation. This combined 'top down' and 'bottom up' approach created consensus in the system.

CSISA's guidance, combined with the effects of recurrent drought-like conditions in Bihar during 2012 and 2013, helped convince the Bihar DoA in 2013 to change its official advisory on planting dates to recommend that wheat should be planted *before* November 15. This revised advisory has helped expand the area under early wheat sowing. CSISA data shows that 340,000 farmers in Bihar and 280,000 farmers in eastern Uttar Pradesh practiced timely sowing of wheat by the end of CSISA Phase II. CSISA-supported service providers established 40,000 hectares of ZT wheat during the 2014–15 wheat season, and 68% increase over the previous year.

On farm diagnostics also revealed important companion measures that can facilitate timely planting. In the rice–wheat cropping system, paddy is typically harvested and left in the field to dry until it is fit for manual threshing. During these 'threshing bottlenecks,' residual moisture is often lost as farmers leave their crop drying in the sun. This stage also results in an 8 to 10-day delay in wheat sowing. CSISA encouraged farmers to use mechanical threshers to eliminate field drying. By creating 150 service providers for axial flow threshers, CSISA helped farmers advance wheat sowing by 9–13 days.

CSISA considers service provision an integral part of our delivery model, and the project has support the emergence of more than 1,900 service providers in Bihar and EUP who provide a variety of custom services to a large number of farmers (see *Growing the Service Economy* below).

New Varieties

CSISA research indicates that changing the varieties used can maximize the overall productivity of a cropping system. For example, short-duration rice followed by long-duration wheat results in higher yields than long-duration rice followed by short-duration wheat. Promising long-duration wheat varieties such as HD 2967, PBW 502 and PBW 343 yielded 4.58 t/ha on average when sown in November, compared to the short duration varieties PBW 154, PBW 373 and HUW 234, which yielded 3.3t/ha when sown during the same period. CSISA's field survey results indicate that in 2012–13, 42% of respondents used long-duration wheat varieties which rose to 68% in 2014–15.

During 2012–15, partners in national programs released 49 new wheat varieties in India, Nepal and Bangladesh, which proved attractive to farmers and stakeholders due to the 5–10% agronomic superiority over the best check varieties, along with disease resistance, good bread making quality and capacity to cope with heat and drought stresses. These varieties have rapidly entered the formal seed systems with wheat cultivars from CSISA holding an 18% share in India, 24% in Nepal and 34% in Bangladesh in terms of seed produced by national and state seed corporations. The share in 2011 was less than 5%.

Wheat varieties developed through CSISA are resistant to all three rusts in South Asia, with most having adequate levels of Ug99 and spot blotch resistance. Quantitative trait loci for both biotic (rust, spot blotch) and abiotic stress (heat, drought) tolerance were identified.

Weed Management

In theory, the complex weed flora in the rice–wheat system of Bihar can be managed manually because landholdings are small. In practice, losses due to weeds are serious because labor is scarce and costly. The adoption of new safe and effective herbicides in rice and wheat has helped farmers reduce yield gaps while reducing labor inputs. Since complex weed flora is the main issue in these ecologies, combinations of herbicides were also tested.

CSISA targeted *Phalaris minor*, a major grass weed, and *Physalis minima*, a weed that is difficult to control using existing herbicides. Three herbicides or herbicide combinations (sulfosulfuron + metsulfuron, clodinafop +metsulfuron and carfentrazone) were tested for season-long weed control, depending on the spectrum of weed flora. The combination of sulfosulfuron + metsulfuron proved most effective and increased the grain yield of wheat from 3.21 t/ha in the standard check to 4.48 t/ha. In *Physalis* dominated areas, carfentrazone alone brought about a yield increase of 0.77 t/ha. Using these research results, CSISA worked with extension agencies, private sector companies and dealers to increase the availability of appropriate herbicides in local markets.

As part of good agronomic practices, CSISA also encouraged the efficient use of herbicides by training its partners, including service providers, dealers, distributors and managers of private sector companies, on proper herbicide spraying techniques. CSISA also provided strategic advice to private sector companies on how weed problems differ across ecologies and how markets can evolve in response to changes in the dominant weed flora. A survey of input dealers in Bihar and EUP showed that the area under herbicide combinations increased from 21,761 ha in 2013–14 to 44,434 in 2014–15, which was a direct result of CSISA's efforts.

Precision Nutrient Management

The balanced use of nutrients is necessary not only to improve profit margins but also to maintain soil health. Management based on soil test values is difficult because adequate soil testing infrastructure is generally lacking across South Asia – even in India – and alternatives are required that improve productivity without the costs and logistical challenges of soil testing. The ICT-based Rice–Wheat Crop Manager (RWCM) is a robust decision framework that develops precise soil fertility recommendations based on knowledge of the landscape and farmer-reported information on management practices and cropping history.

In CSISA field trials conducted in EUP and Bihar, grain yields were 0.39 to 0.54 t/ha more from RWCM compared to farmers' practice. N and P rates decreased 15 kg/ha and 9 kg/ha, respectively, but K_2O rates increased 22 to 45 kg/ha. The cost of additional K was compensated for by higher yields. RWCM proved better than farmers' practice and the state recommendation at all locations, providing an important proof of concept that establishes the value of the approach.

Growing the Service Economy to Enhance Access to Mechanized Technologies

Tractor ownership in Bihar is confined to less than 10% of relatively wealthy farm households. Since tractor and ZT drill ownership is not a tenable goal for most capital-constrained smallholders, their access to ZT technology hinges on affordable access to custom hire services. Expanding the network of ZT service providers (SPs) has therefore been one of CSISA's core objectives since 2009. The SPs serve as 'change agents' by informing fellow farmers about ZT and its benefits and offering respective services, which enhance farm productivity and income on the side of the clients and, at the same time, can constitute an attractive income source for the SPs. CSISA's activities have included awareness raising campaigns, identifying potential SPs, facilitating their interaction with the Department of Agriculture to enable business development aligned with DoA priority setting, facilitating the purchase of ZT drills, and providing training and backstopping on the proper use of the machines and best agronomic practices in general.

In 2010, the first full year of CSISA Phase I, a total of 17 ZT SPs were documented in Bihar and EUP. In 2013–14 alone, the project supported the emergence of 421 additional ZT SPs. By the wheat season 2014–15, 1,624 active ZT SPs were documented by CSISA. Across Bihar and EUP, over 50,000 hectares of ZT wheat were sown by CSISA-supported service providers in 2014–15, reflecting an area increase of 42% over 2012–13. A census survey conducted among ZT SPs in Bihar in 2013 indicates that, while the average number of farmers serviced remained quite stable at around 20 per SP, the average area serviced per SP increased substantially from 13.0 hectares in 2010 to 32.9 hectares in 2011 and 50.2 hectares in 2012.

Generally, ZT SPs are farmers who use the technology in their own fields and differ widely in their service business ambitions; the area serviced by individual SPs ranges from a few hectares to more than 160 hectares per wheat season. In the 2012–13 wheat season, the average gross margin of ZT service provision amounted to US$ 7.76 per hectare. A profitability analysis that accounts for fixed costs related to machinery depreciation reveals substantial economies of scale. With respect to area serviced, the top 25% of SPs, servicing > 40 hectares and focusing especially on relatively large client farmers, earned an average net profit of US$ 1,284 in the 2012–13 wheat season. Under the current 50% subsidy policy for ZT drills, at least 18 hectares need to be serviced per year to make ZT service provision in wheat a profitable business. In a zero-subsidy scenario, the break-even area would double to 36 hectares. However, it has to be acknowledged that smaller-scale SPs may not view service provision as a major business opportunity, but may merely want to offset part of the investment costs incurred for using ZT on their own farm; social obligations and the prestige associated with the provision of innovative services may be other motives for engaging in small-scale ZT service provision.

Bangladesh

In Bangladesh, opportunities for increasing wheat production exist not only through bridging yield gaps on currently farmed land or by expanding cultivation to new land, but by transitioning from single to double cropping or foregoing dry season fallows. Dry season fallows are estimated at between 240,000 and 800,000 ha in southern Bangladesh, and CSISA has been working with farmers to establish a crop such as wheat following monsoon season rice. An increasing number of famers are also transitioning away from dry season boro rice in favor of wheat. This change is the result of increasing fuel costs, and hence irrigation costs for pumping, for boro rice, in addition to poor market prices for boro as compared to wheat.

Farmers transitioning into wheat production face a number of challenges, including terminal heat, salinity in formerly fallow environments in southern Bangladesh, and general lack of knowledge of up-to-date best-bet agronomic management, including precision nutrient management. CSISA addressed these issues by utilizing strategic interventions in wheat seed varietal supply and farmer training.

Through training and varietal release efforts facilitated by CSISA and its partners, 25,176 farmers participated in trainings on improved wheat production practices, 20% of which were women. Over 6,000 demonstrations were established through project efforts. These catalytic actions resulted in farmer-to-farmer transfer of information, with data indicating that over 80,000 estimated new farmers adopted wheat in the six hubs in which the project operated between 2010–15. Specific interventions included:

Improved Wheat Varieties

CSISA collaborated with the Bangladesh Agricultural Research Institute (BARI) to develop and release of a number of heat- and salinity-tolerant wheat varieties, including BARI Gom 25, 26, 27 and 28. These varieties were subjected to a wide range of on-farm trials to identify farmer preferences for each variety, after which CSISA partnered with the Bangladesh Agricultural Development Corporation (BADC, the State agency responsible for public variety multiplication like in wheat) and NGO partners to facilitate the dissemination of improved seed at scale. Converting research results into actionable information, CSISA and its partners undertook an aggressive campaign to train farmers in improved wheat production, and to assist BADC and others to release stress-tolerant wheat genotypes.

Nitrogen Management

CSISA research also focused on appropriate nitrogen management as a function of sowing date in formerly fallow and saline environments of southern Bangladesh. Results clearly indicate that national recommendations for nitrogen fertilization of wheat could and should be reduced by 33% (to 67 kg N/ha) without any decrease in yield or profitability for late-sowing farmers in southern Bangladesh. Our results confirmed that farmers interested in graduating from single aman (monsoon) rice to double cropping can successfully grow wheat by replacing dry season fallows in Bangladesh's coastal environments, with potentially large contributions to national cereal production and food security.

Cultivating Fallows

Based on this research, additional efforts were undertaken to identify tracts of fallow and rainfed cropland that could be intensified during the dry season by shifting to wheat cultivation, using limited irrigation to support the crop. This *ex ante* research, which utilized remotely sensed satellite and geospatial data, identified that up to 20,800 and 103,000 ha of currently fallow and rainfed cropland, respectively, could be brought into wheat production using surface water irrigation supplied by low-lift and axial flow pumps (see Mechanization and Irrigation section). Conservative estimates are that this land could produce 101,648–304,994 tons of wheat each dry season, generating between US$ 11.62–34.86 per dry season for each of the new wheat farmers, compared to only US$ 9.07–27.20 for boro rice, due to higher production costs for the latter. This could result in between 9–26% more wheat produced per year at the national scale, compared to less than 3% for boro rice.

Nepal

Programming in Phase II in Nepal focused primarily on innovation and technology verification at the behest of the USAID mission. Key results for wheat include:

Zero Tillage

Building on CIMMYT's earlier work on technology verification and out-scaling through service providers, CSISA demonstrated and evaluated zero tillage wheat using both two-wheel tractor and four-wheel tractor seed drills, comparing ZT with conventional tillage in farmers' fields. In almost all sites, zero till seeded wheat out-yielded the conventionally seeded wheat. Due to crop establishment cost savings (ca. US$ 250 per hectare), there is already a huge demand for ZT wheat for the upcoming seasons and CSISA is working on the value chain aspects of machinery availability to support adoption at scale.

Fertilizer Management

CSISA conducted on-farm evaluations of different improved wheat varieties under two different fertility levels, i.e., existing farmers' level (65:35:9 NPK kg/ha) and the recommended level (100:50:50 kg NPK per ha). Results show that with an additional investment of US$ 60 per hectare in fertilizer, farmers can increase grain yields by more than 1 t/ha, increasing profitability by US$ 140 from one hectare of land. Further, evaluation results show that the use of a precision spreader for urea topdressing in wheat improves yield by 9% under farmers' fertilizer levels and by 12% under the recommended level of N application, compared with the farmers' application method. This low-cost method of improving precision is suited for both large and smaller farms and can be deployed by women.

Varietal Replacement

Seed replacement rates for wheat are very low in the hills, and are considered one of the major factors responsible for low yields. CSISA conducted on-farm evaluations of new varieties under improved management practices (60:30:30 NPK kg/ha), comparing them with local varieties grown with the same management. All improved varieties produced 40–60% higher yields as compared to the local variety; companies and the government have taken note and are now working with CSISA to increase seed availability in the hills.

RICE

Rice provides the foundation for most diets in Eastern India, Bangladesh and the Terai communities in Nepal. The productivity of many of these rice-based cropping systems in South Asia is low, however, because of biotic and abiotic stresses exacerbated by late planting, poor weed management, low input use, and limited access to irrigation which has profound implications for crop productivity in the current scenario of increasing monsoon variability. In addition, market infrastructure is comparatively weak and most farmers have small and fragmented land holdings.

To support rice production in Phase II, CSISA focused on collaborations with the private sector to support input dealers in order to increase farmers' access to new products, especially hybrids and new classes of safe and effective herbicides that were previously unavailable. CSISA also leveraged ongoing government and livelihood initiatives to strengthen agricultural programming around good agronomic practices.

India

Crop Establishment Methods

Machine transplanted rice under puddled and non-puddled conditions is taking hold in all hub domains through service provision. In Odisha, CSISA significantly increased its focus on machine transplanted rice. From a very low base at the beginning of Phase II, the number of SPs for machine transplanting has increased from 19 in 2013 to 152 in 2015, which has led to an increase in area from 40 ha in 2013 to 2,657 ha in 2015. In Bihar and EUP, the number of SPs increased from 13 in 2012 to 109 in 2015, which resulted in an increase from 208 ha in 2012 to 905 ha in 2015.

Based on 240 crop cuts from farmers' fields, machine transplanting of non-puddled rice (MTNPR) yielded 0.7 t/ha higher than the current practice of puddled transplanted rice (PTR), whereas the direct seeded rice (DSR) yield was similar to PTR but with higher profitability due to cost savings.

As a complimentary effort to work on new establishment methods, CSISA has generated awareness about the business opportunities for nursery enterprises. Such enterprises can support rice transplanting immediately after the onset of rains with appropriately-aged rice seedlings, thereby avoiding scenarios of low or no yield that are common with delayed onset of the monsoon.

Direct seeded rice, another cost-saving crop establishment method, was undertaken in all CSISA hubs in India. In Bihar and EUP, DSR and

PTR yields did not differ on average. In Odisha, drill seeding of rice was introduced as an alternative to 'beushening,' (in which farmers use high seed rates and then plough to thin populations and reduce weeds) and resulted in increased yields by 0.2 t/ha with drastically reduced labor and total costs of cultivation. Inspired, Odisha farmers started purchasing drill seeding machines. The number of SPs for drill-sown rice increased from 0 in 2013 to 49 in 2015, and the area under drill-sown DSR increased from 0 to 1,133 ha.

Improved Weed Management

Weed control in general is very poor in eastern India and in paddy is mostly done by hand. However, because of the rising scarcity of labor at critical times, hand weeding is either delayed or insufficient, leading to higher yield losses. Moreover, labor costs are rising, so manual weed control is becoming uneconomical. Therefore, integrated weed management (herbicide followed by hand weeding) and new and safe herbicides were introduced to reduce rice yield losses caused by weeds. Based on crop cut data, yields increased from 0.6 to 1.2 t/ha with the integration of herbicides compared to farmers' practice of hand weeding. Because of effective control provided by bispyribac, its sales have increased. Data collected from input dealers and distributors shows that the area under bispyribac increased from 30,000 in 2012 to 38,000 ha in 2014 in Bihar and from 45,000 ha in 2012 to 59,000 ha in 2014 in EUP.

Hybrid Rice

Hybrid rice performed better than inbreds under all crop establishment methods. Based on crop cut data from farmers' fields, yield gains ranged from 0.3 to 0.7 t/ha under different crop establishment methods. This led to an increase in the area under hybrids in both Bihar and EUP, although the increase was higher in Bihar. Based on CSISA's input dealer survey, the area increased from 80,000 ha in 2012 to 133,333 ha in 2014 in the Bihar hub domain. Similarly, the area under hybrids increased from 29,000 ha in 2012 to 41,000 ha in 2014 in the EUP hub.

In the rice–wheat system of the EIGP, farmers generally transplant rice late and grow long-duration varieties, resulting in lower yields for rice and for the system as a whole by delaying the wheat crop. In a study conducted at the CSISA research platform at ICAR-RCER, Patna, shorter and medium duration hybrids with 15–20 or 30-day old seedlings performed equally well across all nursery seeding dates except the last seeding date (Aug 2). With longer duration inbreds, yields started declining after the July 6 nursery sowing date with much higher yield losses with older seedlings. These results suggest that short- to medium-duration hybrids offer more flexibility in terms of the window of nursery seeding date as a resilience strategy if rainfall is delayed.

CSISA conducted a study at Orissa University of Agriculture and Technology, Bhubaneshwar to identify optimum nursery seeding dates for boro rice to minimize cold and heat stress at early and terminal stages, respectively. Results showed that nursery seeding in the first half of January (for both hybrids and inbreds) avoids both cold and terminal heat stress and hence yielded the most (6.0 to 6.5 t/ha). There was a drastic reduction in the yields of both hybrids and inbreds when the nursery was seeded on or after January 31. These results suggest that hybrids offer a longer and more flexible window for nursery establishment, including early nursery establishment to avoid terminal heat stress. Establishing a nursery early can also facilitate systems intensification by allowing a legume crop after the boro season.

Strategic Agronomic Research

Results from 5 years of research at CSISA's research platform at the Central Soil Salinity Research Institute, Karnal, indicate that high rice yields can be achieved with low resource use and low environmental footprints [low global warming potential (GWP)], while still increasing profitability. Zero-tilled direct-seeded rice yielded similarly to puddled transplanted rice with 40% less irrigation water, 34% less energy input and 32% lower GWP, while increasing net income by 16%. Within transplanted rice, best management practices such as line transplanting, younger seedlings (20–25 days old), alternate-wetting and drying of water management coupled with optimum fertilizer and weed management resulted in 0.9 t/ha increase in yield and 36% increased in profitability compared to PTR, and that also with 21-24% lower irrigation water, energy and GWP.

Nutrient Management

In collaborations with state universities and government partners, CSISA developed the ICT-based Rice Crop Manager (RCM) and Rice–Wheat Crop Manager which are decision tools that provide location-specific fertilizer recommendations for farmers growing rice in Odisha, and rice–wheat in Bihar and EUP. Based on 129 on-farm evaluation trials, RWCM increased rice yields in EUP and Bihar by 0.5 t/ha compared to current farmers' practice, with a reduction in N by 9 kg/ha and P_2O_5 by 35 kg/ha, and an increase in K_20 by 12 kg/ha. Similarly, RCM in Odisha increased rice yields by 0.7 t/ha with a reduction in P_2O_5 by 16 kg/ha and K_20 by 14 kg/ha, and an increase in N by 30 kg/ha.

Weed Management

On-farm weed control studies demonstrated that new herbicides can improve cereal yields and can reduce labor constraints. In rice, new herbicides (bispyribac + pyrazosulfuron) with spot hand-weeding on average increased rice yield by >20% compared to current farmers' practice, providing effective control of complex mixed weed flora. The application of pre-emergence herbicides + spot hand-weeding also improved yields compared to the current farmers' practice of two hand-weedings. CSISA research also showed that pre emergence (pendimethalin or pretilachlor) followed by post emergence (bispyribac or fenoxaprop + ethoxysulfuron) controls weeds effectively in DSR.

Water Management

Adaptive research on water management in the dry (boro) season in Odisha identified alternate wetting and drying (AWD) as one of strategy to increase the area under rice and to reduce fallow land. AWD adoption, though, is influenced by many biophysical and social factors including pump ownership, distance from the pump, leveling of the field and weed management.

To reduce the costs and energy investment in irrigation, CSISA explored the impact of land configuration and slope on non-productive water losses. In sandy loam soil, there was ~15% irrigation water saving with 0.1% slope without any yield penalty. On farm evaluation in Bihar has also indicated similar results for maize and rice.

Rice Breeding

During Phase II, CSISA focused on enhancing genetic yield potential, trait development for dry direct seeding, heat tolerance, and fodder quality improvement. In addition, progress was made in the development, testing and release of cultivars with these traits. CSISA used marker assisted breeding to improve the yield potential of 7 varieties, and cloned genes such as high grain number, larger panicle size and strong culm. Recurrent selection using 26 parental lines was used and a base population of more than 50,000 plants was developed. About 4.3% of the families had more than 20% higher grain yield than the check.

For direct seeing conditions, CSISA found new donors for traits relevant to anaerobic germination, early vigor, root length density, proportion of lateral roots, response to fertilizer and nutrient use efficiency, lodging resistance and other traits. CSISA also developed and tested new varieties for tolerance to high temperatures. One hundred sixty lines are in observational yield trials and advanced heat-tolerant lines were nominated to multi-location evaluation trials and many entries are in the international heat tolerant nursery. Five varieties suitable for dry-DSR were released in India and 12 lines are in advanced stages of testing in All India Co-ordinated Rice Improvement Program.

More than 400 entries under DSR and 360 entries under puddled transplanted conditions were evaluated in national level network trials.

More than 1,500 entries were tested for straw digestibility traits and many promising breeding lines with better straw digestibility traits and high grain yield potential were developed. A few promising lines were used in the crossing program by NARES partners to develop an array of new breeding lines with high grain and fodder yield, better grain quality and straw digestibility.

BANGLADESH

Closing Yield Gaps

CSISA-Bangladesh conducted 3,598 aman season and 2,466 boro season rice trials and demonstrations between 2011 and 2015 in which farmers followed the crop production practices recommended by CSISA staff. The data revealed a large gap between the grain yields that farmers could attain and what is typically attained. Based on these results, CSISA recommended farmers use Good Agricultural Practices (GAP): modern, high-yielding varieties and young seedlings transplanted on time, at the correct spacing and grown using the recommended fertilizer rate. Using GAP, grain yield increased by 10.2% in the aman season and 9.9% in the boro season compared with farmers' practice.

Analysis of data from 1,522 data points from boro rice trials and demonstrations conducted during the life of the project clearly show the importance of seedling age and time of transplanting. Grain yield declines sharply when moving from 15-day old seedlings to 35-day old seedlings. Critically, for every day from 15- to 25-day old seedlings, yield dropped by 200kg/ha/day. Time of transplanting boro rice is also critical. Analysis of data from 1,530 data points from boro rice trials and demonstrations shows a yield loss of 39kg/ha for each day transplanting is delayed after January 1. Delaying transplanting to the end of January would therefore result in a yield loss of 1,210 kg/ha or approximately 17% of a 7-ton rice crop.

Planting Methods

CSISA-BD conducted a number of trials at all hubs in 2013 and 2014 to determine if puddling was necessary and if alternative ways of establishing rice were possible. The results showed that zero tillage (transplanting into uncultivated wet soil) gave both a lower grain yield and much lower profit. This was largely because the cost of transplanting into soil by hand into land that had not been cultivated was much more time consuming and because weed control was very poor. A single pass of a power tiller improved weed control but hand transplanting into a hard soil surface was still difficult. However when a rice transplanter was used on plots that had been cultivated with a single pass of a power tiller, grain yield was increased by 11% compared to that from conventionally puddled and manually transplanted rice.

Another approach is to sow rice directly. A series of trials conducted at the BARI regional research station in Jessore showed that that this not only increased rice grain yield and profit but also benefitted the two other crops in the rotation under test, wheat and mungbean. This minimal tillage package was therefore more productive and profitable than the normal puddled aman followed by boro rice system. The optimal sowing date for a medium duration aman rice variety DSR sown was the last week of May when the chances of heavy rain are minimal.

Improved Varieties

On land that was submerged for part of the growing season data from trials and demonstrations indicated that newly released medium- to long-season varieties such as BRRI dhan52 will yield more than varieties such as BR11 released in the 1980s. Where the plots were not submerged there was little difference between the grain yield of the more recently released varieties and the older varieties. The medium maturing BRRI dhan49 will, though, provide almost the same grain yield in 135 days on land not prone to submergence as the longer duration BR11 and BRRI dahn52 will yield in 145 days. This allows farmers to plant dry season crops earlier than would be possible if they planted long duration varieties.

Aman varieties that mature in 110 days or fewer would allow farmers to harvest aman rice in late October and plant rabi crops in early November. Early planting of winter crops significantly increases grain yields and can also facilitate the transition to triple crop systems. CSISA-BD conducted 20,277 cropping system demonstrations in which the cultivation of short duration aman varieties was a key component of these new systems. These demonstrations invariably showed that they were more profitable than systems based on long-duration aman varieties.

Nepal

Hybrids

In Nepal, varietal replacement rates for rice are very low. Farmers are still growing relatively old rice varieties that have low yield potential and disease susceptibility. Rice yields can be increased substantially with a switch to newer, shorter-duration varieties that also enable timely planting of winter season crops. In CSISA's evaluations, all hybrids produced significantly higher yields compared to other improved varieties. Among the evaluated hybrids, DY 69, Kailash and Aakashhad produced the highest yields and produced approximately 2.0 t/ha higher yields than the commonly grown improved variety, Sabitri. All tested hybrids produced 1–2 t ha^{-1} higher yield under both high and low fertility levels, suggesting gains in grain productivity and fertilizer use efficiency are attainable for all types of farmers through the adoption of rice hybrids. CSISA is also working with seed suppliers and local agro-vets to provide market intelligence on where hybrids can be most sensibly be introduced.

Direct Seeded Rice

Machine-sown dry direct seeded rice (DSR) is fast emerging as a cost-effective technology that allows the direct line sowing of rice seeds into non-puddled fields and avoids the cost of raising rice nurseries and transplanting seedlings. Across evaluation years and sites, CSISA data suggests that there was no difference in grain yield between DSR and transplanted rice. However, there were savings of around US$ 200 per ha in crop establishment costs with DSR. Similarly, in all sites rice planted under DSR matured 7–10 days earlier than transplanted rice, which increases the window for the timely seeding of winter crops. CSISA is working to increase the market availability of seed drills in Nepal to aid the expansion of DSR rice and ZT wheat.

Fertilizer Management

CSISA evaluated promising hybrids under four different levels of N (i.e., 0, 50, 100, 150 kg/ha) and compared with the improved varieties commonly grown in each location. At every input level, the response to applied nitrogen was higher for hybrids across evaluation sites as compared to the improve varieties. Our data suggests a consistent advantage of 0.5-1 t/ha for the adoption of hybrids with fertilizer application above 50 kg N/ha compared to improved varieties. For hybrids and improved varieties, nitrogen application beyond 100 kg/ha results in diminishing economic returns suggesting that the selection of crop cultivar has less influence on optimum fertilizer rates than originally anticipated. A CSISA-NARC on-station evaluation of fertilizer management for different varieties shows that it is possible to double the yield of upland rice with the application of 80kgs of N per ha as compared to no fertilizer application (prevailing farmer practice), highlighting the importance of improving fertilizer value chains in the hills.

Weed Management

Intense weed competition in upland rice is very common due to a favorable environment (high temperature and enough soil moisture) and the absence of persistent flooding. Manual weed management, which is typical farmers' practice in upland rice, is difficult and highly labor intensive. Use of Pendimethalin, a pre-emergence herbicide, was found to be highly effective for controlling weeds during initial crop growth and led to significantly increased grain yield compared to hand weeding at 25–30 days after seeding. Gross margin achieved with the use of Pendimethalin doubled (gross margin US$ 300/ha) compared to hand weeding at 25 days after sowing (gross margin US$ 150/ha). Depending on how farmers value their own labor, the use of herbicides in tandem with cultural methods offers opportunities to transform the profitability of upland rice production in the hills.

MAIZE

Maize is an important component of agricultural diversification, intensification, intercropping and value addition, including as animal feed. It is also frequently the cereal crop that provides the most livelihood opportunities for women. The vulnerabilities that affect maize productivity in CSISA's working domain include occasional excess water due to monsoon rains, a shortage of water for winter and summer season maize and perennial weeds such as *Cyperus rotundus*. In all ecologies, the success of maize production also relies on linking producers with value chains as an incentive for intensification.

INDIA

Decomposing Yield Gaps

Farmers' practice in maize cultivation involves planting around 45,000 plants per hectare and applying around 80:40:40 kg/ha of N, P_2O_5, and K_2O, resulting in yields of around 3 t/ha. CSISA's research conducted in farmers' fields during kharif 2013 and 2014 determined that optimal plant population is around 70,000 plants/ha and optimal fertilization is 140:50:75 kg/ha of N, P_2O_5, and K_2O. These factors added 0.8–1.05 t/ha and 0.66–0.94 t/ha in yield, respectively. Improved weed management added 0.18–0.17 t/ha. When all of these interventions were layered (best bet agronomy), grain yield increased from 3 t/ha (farmers' practice) to 5.20 t/ha under conventional tillage and 4.70 t/ha under conservation tillage (strip till), a yield increase of 1.7–2.2 t/ha over current farmers' practice.

Hybrids

In CSISA's hybrid evaluations, maize yields decreased in the following order: long duration (6.85 t/ha) > medium duration (5.7-6.0 t/ha) > short duration (5.0 t/ha) > high-yielding long duration inbred (3.5 t/ha). In a crop-cafeteria trial conducted in 2015 comparing maize hybrids of different maturity classes, results showed that long-duration hybrids generally yield higher than short-duration hybrids, with some variability occurring within a maturity class. In Bihar and Eastern UP, CSISA trials of short-duration hybrids in kharif obtained yields between 4.5 t/ha and 3.9 t/ha, and rabi season trials of hybrids of all durations yielded between 8.2 t/ha and 5.5 t/ha demonstrating the importance of varietal selection. These data have been shared with companies and the State Departments of Agriculture to inform market development and subsidy programming.

Crop Establishment Methods

In order to save water during rabi, bed planting was tested and validated at sites across Bihar and EUP. When compared with line sowing, the three-year average grain yield was 7.6 t/ha, compared with 7.1 t/ha with flat sowing. In kharif, bed planting helps maize withstand heavy rainfall. Across all locations, sowing maize on beds in kharif increased yields by 0.8 t/ha.

The rice–maize cropping system is quite common the EIGP. The effect of puddling on the maize crop was studied during 2012–13 and 2013–14 at the ICAR research complex in Patna. Puddling at the time of rice transplanting in kharif decreased the grain yield of the following maize crop in rabi to 6.5 t/ha, against 7.9 t/ha when maize was grown after non-puddled rice. Maize was very responsive to zero tillage and the best yield levels were attained when rice residues were retained on the surface. The maximum grain yield of 8.3 t/ha maize was obtained when the maize was sown with zero tillage with 50% retention of rice residue.

Nutrient Management

To develop a decision-support tool for site-specific nutrient management in maize, nutrient omission plot technique trials were conducted in red and lateritic acidic soils of the plateau region of Mayurbhanj, Odisha during kharif 2013 and 2014. Average results revealed a 4.66 t/ha response to N, a 4.98 t/ha response to P, and a 1.14 t/ha response K, over yields achieved with indigenous sources of each nutrient only, suggesting that these soils are highly degraded and that balanced fertilization is essential. Nutrient management decision tools increased maize yields from 3.67 t/ha to 5.39–6.06 t/ha (1.72–2.40 t/ha gain in yield over current farmers' practice).

Integrated Weed Management

Atrazine pre-emergence followed by one mechanical weeding resulted in yields (7.25 t/ha) similar to weed free yield (7.35 t/ha). Similarly, new herbicide combinations (tank mix of halosulfuron or tembotrione or topramesone with atrazine) also resulted in yields similar to weed free check (7.1 to 7.25 t/ha). The yield under current farmers' practice of weed management (earthing up once at 21–30 days after seeding) was 5.73 t/ha. The pre-emergence application of atrazine only increased the yield to 6.65 t/ha.

Bangladesh

In Bangladesh, maize means money for smallholders. Rising incomes and changing dietary patterns that prioritize animal protein in Bangladesh have encouraged the growth of maize production, which has spread from 0.02 to 0.36 M ha in the last decade. A well-managed and high-yielding maize crop can fetch over US$ 1,000/ha in net profits when sold to the commercial feed industry. In addition to having dramatically lower production costs than boro rice, which can require over 20 irrigations per season, maize is attractive for farmers interested in income generation.

Maize is a relatively new crop in Bangladesh, and farmers often lack timely information on how to use better-bet agronomy to grow a profitable crop near optimal yield levels, which can reach up to 16 t/ha, the region's highest. Maize has spread where favorable markets exist, and where value chains including post-harvest aggregation, transport, and handling are well developed. Hence, while maize can offer considerable opportunities for farmers, smallholders need to be linked to markets and empowered to grow profitable crops using strategic and science-based agronomic management.

CSISA has partnered with the Department of Agricultural Extension and NGOs to train new maize farmers in areas that have market potential, and by working to develop input and output markets that would allow maize cultivation to be profitable. Beginning with on-farm, adaptive research trials to fine-tune management recommendations for smallholders, CSISA partnered with local NGOs and the Katalyst project to develop value chains supporting maize production input and grain sales output markets. Additional effort in the CSISA mechanization and irrigation (CSISA-MI) project has focused on developing small-scale agricultural machinery suited for rapid yet precise maize sowing and fertilization. Additional efforts were made to promote mechanized maize shellers to reduce the post-harvest labor burden in maize processing, especially for women farmers who are often responsible for this work.

Research on a decision-support tool for maize also resulted in a prototype to support custom nutrient management recommendations for maize farmers. Also, CSISA trained and educated farmers not only in best-bet agronomy, but also in the logic and sense of simple yet effective business management skills, with emphasis on pre-season planning. These pre-season planning meetings also involved farmers in the development of post-harvest sales and handling plans, including work to directly link farmers to feed mills.

Despite slightly falling maize prices in the last two years, CSISA's efforts to expand maize markets have resulted in considerable progress.

In 2014–15 alone, 3,489 farmers received maize agronomy and market training through CSISA in Bangladesh. In addition to further partnership efforts with key private sector actors, including input suppliers, maize aggregators, and feed mills, these actions had a cascading effect, with an additional 46,855 indirect farmers adopting maize throughout the six hubs in which CSISA has worked, on 8,200 hectares of land. Of this, 1,730 directly supported farmers made use of maize shellers, with another 13,615 indirect farmers utilizing the technology to reduce post-harvest labor requirements. Over 4,000 farmers also took up intercropping of maize with leafy and nutritional vegetables. An additional 150 farmers have experimented with the decision support tool to address ways to maximize nutrient use efficiency and maize yield. At the same time, specialized maize seeders that can be attached to two-wheel tractors, which resulted from collaborative development with the Bangladesh Agricultural Research Institute, are being studied for potential commercial scale-out through specialized market research conducted in partnership with the Syngenta Foundation for Sustainable Agriculture. Initial results are promising, with 4,113 farmers using bed planting services in the last year alone.

Nepal

Expanding Hybrid Maize Options

Testing and evaluation of registered commercial maize hybrids, hybrids developed by NARC, and improved open pollinated varieties for spring and kharif season are key objectives for CSISA. At present, all of the commercially available maize hybrids have been registered for use east of the Narayani River – i.e., the central and eastern regions of Nepal. As a consequence, seed dealers and distributors have been reluctant to stock and actively market maize hybrids in the Mid and Far West due to liability concerns. In three years of collaborative research with farmers, national partners and the KISAN project, CSISA has identified five well-performing hybrids that can be prioritized for registration in new areas – namely Rajkumar, Nutan (Kanchan 101), Bio. 9220, Pioneer 3785 and TX 369. In all three years of evaluation, these hybrids significantly out-yielded the open pollinated varieties and other hybrids for spring (Terai) and summer (hill) seasons, suggesting broad adaptability.

For the market development and commercialization of those hybrids in new zones, CSISA coordinated with the national-level variety release and registration committee that is composed of representatives from NARC and Seed Quality Control Center. CSISA shared research findings on hybrid performance and the committee expanded the geographic registration of the best performing hybrids to the Mid and Far West. As a result of these efforts, the private sector has now taken the lead to develop markets for newly registered hybrid and supplied over 3 tons of hybrid seed with promotional pricing efforts in these geographies.

Scale-appropriate Mechanization

The manual seeding of maize in lines is tedious and requires a large amount of labor, which increases the total production cost. CSISA has been demonstrating and evaluating different types of scale-appropriate machinery for seeding maize both in the hills and the Terai to evaluate the crop establishment and economic benefits of each machine, as compared to manual seeding. Seeding costs related to all of the machinery used for seeding maize are lower compared to manual seeding. Scale-appropriate mechanized seeding options for maize help ensure precision stand establishment (increasing yields by 50%) while reducing planting costs by half.

SYSTEMS OPTIMIZATION

India

Drought-like conditions experienced in Bihar during 4 of the last 6 years highlight that farmers' profits are constrained by uncertain rainfall patterns during the monsoon season and terminal heat during the rabi season. CSISA and its partners have been engaging with farmers and extension agencies to build resilience to climate variability. CSISA has found that: adapting to climate variability means improving cropping *systems*, not just individual crops; mechanization is essential to intensifying cropping systems at a relatively low cost; the utilization of fallow lands is key for increasing overall productivity; and complementary changes may be needed in government policy to maximize benefits and spread innovations.

Intensification and Diversification of the Rice–Wheat Cropping System

In order to improve the overall productivity of the dominant cropping systems of the EIGP, CSISA validated the productivity of a variety of cropping systems in farmers' fields. They were further tested and refined under best management practices at the experimental farm of the Indian Agriculture Research Institute, Pusa. The highest-yielding systems were: maize followed by (fb) mustard (6.4 t/ha wheat equivalent yield), maize fb wheat (7.7 t/ha), rice fb mustard fb mung bean (9.0 t/ha), rice fb wheat (9.1 t/ha), and rice fb mustard fb maize (11.9 t/ha). These results mean farmers can grow mustard starting from mid-October and harvest at the end February or March, leaving enough time to grow maize or mung.

CSISA's profitability analyses indicate that the most profitable system is short duration rice fb mustard fb mung bean (US$ 2,226/ha), with the next most profitable systems being: short-duration rice fb mustard fb maize (US$ 1,880/ha), medium-duration hybrid rice fb long-duration wheat (US$ 1,143/ha), long-duration rice variety fb short-duration wheat (US$ 988/ha) and short-duration rice variety fb long-duration wheat (US$ 837/ha).

Based on average sowing dates for wheat, short- or medium-duration hybrid rice with a maturity period of 120 to 135 days followed by long-duration wheat appears to have significant scaling potential for the EIGP. The average date of wheat sowing after long-duration rice varieties is November 29, whereas the average date of wheat sowing after hybrid rice is November 18. Overall yields were higher when hybrid rice was planted, followed by wheat.

CSISA worked diligently with private sector partners to increase the availability of hybrids in the market. Data collected from private sector partners in 2015 revealed that hybrid rice and long duration wheat varieties covered 174,656 ha and 72,809 ha, respectively across the Bihar and EUP hub domains. Coverage of rice hybrids and long-duration wheat varieties grew by 35% and 26%, respectively, over the previous year.

Intensification of the Rice–Fallow Cropping System

The rice–fallow cropping system of Odisha provides a vast scope for system intensification. Replacing the fallow, CSISA worked to broaden the scope of crops like maize, wheat and chickpea in the partially irrigated areas of the plateau while promoting mung bean, black gram, chickpea and mustard in rainfed environments.

CSISA cultivated un-irrigated areas either currently fallowed or cultivated with 'low input–low output' pulse systems during rabi under zero till or conventional till line sowing. The intention was to capitalize on the residual moisture left by the preceding rice crop, as irrigation facilities are scarce and there is almost no rainfall during rabi. Research results show that mung bean has significant potential due to the relatively high yield and market price.

Following the rice crop, mung bean was tested under broadcasting, ZT line sowing and conventional till line sowing. These systems were compared to the rice–fallow system. The soil mulch created by conventional tillage protected the mung bean against soil moisture loss by breaking the capillaries that restrict water loss through evaporation during the active growth stage, and improved the performance of this crop after the rice harvest. Since there is very little scope for post-sowing irrigation, CSISA focused on mung bean with conventional tillage. Paddy yields of 5.0 t/ha and mung bean yields of 2.7 t/ha are possible with very limited inputs to the mung bean crop.

Intercropping and Diversification in Maize-based Cropping Systems

Hybrid maize during rabi covers almost 90% of the cropping area in Bihar. Hybrids however, have not been fully accepted during the rainy season. CSISA has reached out to 3,000 farmers through 200 self-help groups and provided trainings and capacity building on the cultivation of hybrid maize during kharif. CSISA research has shown that maize + turmeric was the most productive intercropping option, but its wide adoption depends on the volume that the market can absorb. Similarly, in rabi, maize +peas was the most productive, but adoption was higher for maize + potato.

In Odisha, CSISA targeted subsistence rice farming areas as well as fallow areas of Mayurbhanj to introduce hybrid maize cultivation, which can be quite remunerative. In 2015, 273 ha of hybrid maize were planted using seed-cum-fertilizer drills, although accessibility to promising maize hybrids was a challenge. On-site availability of such hybrids was ensured through private sector partnerships between CSISA and major seed companies. To avoid distress sales of green cob maize, farmers were trained on post-harvest practices and were linked to potential markets (e.g., private companies, poultry feed mills) so that they can shift to selling maize as dry grains. Farmers were able to sell their maize grain at US$ 21-23/quintal against US$ 15-17/quintal sold last season. Women farmers became an integral part of this process. In 2015, 395 women farmers linked to 42 self-help groups adopted line sowing of hybrid maize and best-bet agronomic practices promoted by CSISA to reap the highest yield yet achieved in the plateau.

Bangladesh

Diversifying the rice–rice cropping system

It is estimated that some 51% of cropped land in Bangladesh is planted to a two-rice crop per year system – aman rice followed by boro rice. However, CSISA-Bangladesh conducted 9,149 demonstrations to show farmers that by planting short-duration aman rice varieties they could plant a mustard crop between aman and boro rice crops, finding that farmers could gain an extra US$ 441 to US$ 589/ha. Replacing boro rice with lentil followed by mungbean would give farmers an extra US$ 877/ha over growing the traditional aman rice followed by boro rice cropping system.

Increasing income by adding another crop to an existing system is possible if farmers adopt short-duration aman season rice varieties and varieties or crops well adapted to growing on land with limited access to dry season irrigation or salinity problems. These systems were demonstrated in 20,277 demonstrations by CSISA-BD. As a measure of the success of this approach some 33% of farmers working with the project had adopted a second or third crop and 33% had adopted short duration aman varieties.

A total of 9,149 demonstrations of rice–mustard–rice systems were conducted by the project, resulting in 33% farmers adopting this system. Data from the 2013–14 aman, rabi and boro seasons showed that gross margins for farmers practicing a rice–mustard–rice system were between US$ 441 to US$ 589/ha greater than those practicing a rice–rice cropping system. Much of the mustard produced in these demonstrations was crushed to produce oil for home consumption increasing the amount of this high-energy food in diets. This is of particular value for children who often do not have sufficient high-energy foods in their diets.

In areas where there is a limited supply of irrigation water in the dry season growing grain legume crops or a combination of mustard followed by mung can be a very profitable way of using this land. An example of this can be shown from demonstrations in Jessore where farmers replaced long duration aman rice varieties BR11 or Guti swarma with short duration BINA dhan7 and planted Lentil followed by mungbean instead of boro rice. The cost of growing this system was US$ 199/ha less and produced a gross margin that was US$ 877/ha more than a rice–rice system.

MECHANIZATION AND IRRIGATION

Mechanization increases opportunities for sustainable intensification because it allows crops to be harvested more quickly, to plant successive crops faster and earlier, and to increase production through intercropping or the use of fallows. It can also significantly improve the profitability of farming. CSISA has focused primarily on technologies such as zero tillage, machine transplanting of non-puddled rice (MTNPR), direct seeded rice, axial flow threshing (AFT), axial flow pumps, power tiller operated seeders, and reapers, all of which allow farmers to reduce the costs of production and improve yields.

India

In the CSISA model, mechanization and service provision go hand-in-hand. CSISA has created 1,660 service providers for zero tillage, 109 SPs for MTNPR, 102 SPs for AFT and 40 SPs for laser land leveling in Bihar and EUP. In addition, 152 SPs for MTNPR and 49 SPs for DSR have been created in Odisha. Small businesses are emerging for the most entrepreneurial service providers, who provide round-the-year services, from seed to harvest.

CSISA research indicates that average profits for service providers in Bihar and EUP are US$ 472/year for ZT, US$ 550/year for MTNPR, and US$ 1,036/year for axial flow threshing. Machine transplanting of rice has generated a regular cash flow for SPs in Odisha, with an average profit of US$ 922/year. In Odisha, MTR has also driven down the cost of transplanting by US$ 50/ha for farmers, compared to manual transplanting. DSR fared even better, with an establishment cost savings of US$ 59/ha compared to manual broadcasting.

Research conducted at the Indian Agriculture Research Institute, Pusa found that machine transplanted rice followed by ZT wheat generated net profits of US$ 1,214 and DSR followed by ZT wheat generated profits of US$ 1,214, as compared to farmers' practice of puddled transplanted rice followed by conventional tillage wheat. The system of rice intensification followed by the system of wheat intensification was the least profitable.

Bangladesh

To drive the adoption of more precise and resource-conserving agricultural practices, CSISA-MI promotes three keystone technologies – the fuel-saving, high-volume axial flow pump (AFP) for surface water irrigation; power tiller operated seeder (PTOS), which can be used for line-sowing and conservation agriculture; and the reaper to address labor bottlenecks at harvest and speed up the time between harvest and the planting of the next crop. These machineries help boost yields by maximizing the productive use of soil moisture, fertilizer, and seed, while saving farmers' time, labor, and money. Through public-private partnerships with machinery manufacturers and importers such as Advanced Chemical Industries (ACI), Metal Industries, Chittagong Builders and the Rangpur Foundry Limited (RFL) Group, CSISA-MI is working to commercialize and catalyze the wide-availability of these machines for service providers. Concentrating on power tiller operated tillers, reapers and axil flow pumps CSISA-MI linked 511 trained local service providers with dealers from three major machinery import dealers. With the machines purchased these service providers provided 22,012 farmers with planting, harvesting and irrigation services to grow 5,726 ha of crops.

During FY15 CSISA-MI's direct interventions has led to 5,726 hectares of land being brought under different targeted agricultural machineries and irrigation services. During the period, project supported wheat production in 1,086 hectares of land and supported 3,358 farmers. Similarly, project supported maize production in around 100 hectares of land and 200 farmers. CSISA-MI is working to track copycat enterprises in the project areas. Through this process the project tracked sales of around 660 machines for land preparation mostly in Faridpur and Jessore regions. The project conducted survey among 257 service providers who provided land preparation services to the farmers. The survey revealed that the land coverage by 660 service providers would be 4,200 hectares. Thus the total land coverage under mechanization would be around 10,000 hectares over the last one year.

Out of the direct 5,726 hectares, 2,183 hectares were irrigated by service providers using fuel-efficient axial flow pumps supplied primarily through purchases made from one of CSISA-MI's private sector partner, Rangpur Foundry Limited. Crucially, RFL and the service providers invested US$ 81,000 of their own funds to spread AFP services to farmers. Crucially, RFL and individual service providers invested of their own funds to spread AFP services to farmers.

Over 1,900 hectares were cultivated by using PTOS in a suite of crops including rice, maize, wheat, jute, vegetable crops (onion and garlic), Lentils among others, while improves crop profitability. In order to make this happen, CSISA-MI's private sector partners invested US$ 107,000 of their own funds to expand use of the equipment. An additional 1,624 hectares of wheat and rice were harvested using multi-crop reapers through local service provision and the action of our private sector partners ACI and Metal who demonstrated and advertised to farmers and potential service provider clients.

A key measure of CSISA-MI's success is the willing investment of ACI, Metal, Chittagong Builders and RFL in the machinery technologies supported by the project. All are receiving technical support from CSISA-MI to import and market agricultural machines. These private sector companies are generating demand for the machinery technologies through promotional activities like video road shows, billboards, local newspapers and cable advertisements and other marketing materials. A number of practical demonstrations in local markets (haat-bazar), dissemination of other communications items to enhance the awareness and to motivate potential clients have been done.

Nepal

As outlined in some of the earlier sections, CSISA has tested, demonstrated and disseminated information about a variety of technologies that facilitate easier, faster and more cost-effective crop establishment. Technologies include zero tillage wheat, machine-sown dry direct seeded rice, and strip tilled maize. CSISA has also spent considerable time and effort over the last two years demonstrating reapers for two-wheel tractors and training service providers how to use them.

The project has also collaborated with NARC's Agri Engineering Division, DOA's Engineering Directorate and, just as importantly, various private sector importers, to educate farmers and service providers about reaper attachments, self-propelled reapers, and now mini tiller reaper attachments. Interest in these agricultural machines has been picking up rapidly, and nearly 100 reapers were sold in the 2014–15 rabi season, whereas none had been sold in the previous year.

GENDER

India

CSISA implemented a community-centric model of participatory technology testing, reaching out to marginalized women farmers through self-help groups and their federations. For example, in Bihar, CSISA formed *Kisan Sakhi*, to acknowledge and strengthen the role that women play in farming systems. Through groups like *Kisan Sakhi*, information about CSISA-supported technologies was disseminated to women farmers, who then became the successful early adopters and promoters of these technologies. An example of CSISA's work with women farmers is outlined below.

CSISA collaborated with women's self-help groups (SHGs) and their federations to devise a participatory technology-testing model targeted at women, which aimed to identify the needs of women farmers as they relate to scale-appropriate technology and improved management practices. In Bihar, CSISA collaborated with the government program, *Mahila Samakhya,* its higher-level federation, and Creation Welfare Society, an NGO, to accelerate the adoption of improved technologies that lead to sustainable intensification of cropping systems in Bihar. The four key pillars of this collaboration, manifested as the group *Kisan Sakhi*, are: identity, knowledge, leadership and economic empowerment.

Kisan Sakhi members received classroom and hands-on training on improved technologies that could be appropriate for women farmers. CSISA's collaboration with women's SHGs grew from 248 women farmers in 2014 to 3,000 women farmers in 2015. The technologies adopted by women farmers include machine-transplanted rice, direct seeded rice, mat type nurseries and community nurseries, and improved high-yielding and stress-tolerant rice cultivars.

Kisan Sakhi responded positively towards new technologies, including MTNPR. This technology reduces drudgery by eliminating the uprooting and manual transplanting of seedlings in puddled fields, which is mainly done by women. Machine transplanting also addresses the labor scarcity caused by the outmigration of men. Women's groups purchased machine transplanters and started acting as service providers to other men and women farmers in the area. The first women's service provider group was formed in kharif 2014 and they earned US$ 219 by custom hiring in that season, plus US$ 125 by raising a mat-type community nursery. In 2014, *Kisan Sakhi* grew mat-type community nurseries for 13 Acres and expanded to 70 Acres in 2015.

CSISA also introduced DSR to the women of *Kisan Sakhi*, who found that it saves labor, time the cost of cultivation and water. This technology was introduced to women farmers by providing training about this technology. Depending on the ecology/topography, women farmers were advised to replace their low-yielding varieties with high-yielding varieties, including stress-tolerant rice varieties or hybrids. About 228 women farmers received these stress-tolerant varieties and hybrids in 2015.

Thousands of women farmers adopted improved post-harvest practices including mechanical paddy threshing using the open drum thresher. Trainings were given to groups of women farmers who further popularized the technology and reached almost another thousand women farmers across Bihar. Mechanical threshing saves time, costs and labor, as well as the drudgery associated with hand threshing, and it provides another opportunity for service provision.

Bangladesh

Making use of pond banks (dykes) for the production of vegetables and orange fleshed sweet potato provides an income of US$ 34 from just a 10m^2 plot in 3 months from sowing. A typical 1,000 m^2 pond would have 240 m^2 of bank on which vegetables could be grown suggesting farmers could generate vegetables worth US$ 836 from a relatively small pond. As these ponds are largely managed by women this is income and nutritious food that could be used by women. To encourage the utilization of these pond dykes for vegetable production 4,904 women were given vegetable production and child nutrition training. Training material, including recommendations for vegetable production on dykes were prepared. Mini packs (5 to 10 g packs) of vegetable seeds marketed by the Lal Teer Seeds company were sold to pond owners to facilitate the planting of vegetables on the small plots available on pond dykes. Research was done to determine the best combination of vegetable to be grown on pond dykes.

Incorporating business and aquaculture technical training adds value to gender empowerment training making it easier to understand. Training women in seed production and storage improves the viability and quality of rice and wheat seeds. Business training and linkage events for women entrepreneur's helps women expand existing businesses and embrace new business opportunities.

Nepal

CSISA also worked with women's groups in Nepal to disseminate information about innovative, scale-appropriate technologies. For example, *Loktantrik Mahila Krishak Samuha* (Democratic Women Farmer Group) was formed in 2011 to economically support poor women and to increase their exposure to new agricultural technologies. Since 2013, CSISA has been working with this group on research activities, trainings and demonstrations. For example, group members participated in CSISA's evaluation of rice varieties, as well as trainings and demonstrations on rice production technologies and crop establishment methods. This included exposure to direct seeded rice (DSR) technologies, using both four-wheel tractor seed drills and Chinese two-wheel tractor seed drills.

DSR, a technology that can provide significant cost savings to smallholder farmers, can be particularly attractive when labor availability is constrained as it eliminates the need for nursery bed preparation, puddling and transplanting of seedlings into the main field. DSR also reduces water requirements, while still providing similar grain yields achieved with transplanted puddled rice. All of these benefits accrue to women who are left tending the farm after men out-migrate. Lastly, in the winter of 2013–14, a large number of farmers from the group also participated in adaptive research trials on lentil varietal selection and different agronomic practices. The group members were able to make income by selling lentil seeds, which were produced from the new varieties.

LIVESTOCK

Livestock provides an important complementary livelihood option to farmers in cereal-based systems in South Asia, and is a promising pathway to a better life for millions of crop–livestock farmers. Within CSISA, ILRI helped crop–livestock farmers to boost income and milk production by increasing the availability of fodder, promoting efficient use of cereal residues, and improving the quality of supplementary feeds in India, Bangladesh, and Nepal.

During Phase II, two strands of hub-based activities were implemented with partners and collaborators in CSISA hubs, specifically: (1) technology development and adaptation and (2) capacity development for uptake and scaling out of promoted technologies and best practices. These interventions have brought about tangible impacts, such as higher milk yield (10–14%) and better milk quality (1–3% higher fat content), which translated into higher income from milk sales (additional US$ 50–150/animal/year) and reduction in feed costs (30% savings from less waste due to chopping, for example).

With insufficient feed and fodder supply being a constant problem for all CSISA hubs, ILRI promoted the use of abundant, locally available and underutilized feeds, such as rice and wheat straw and maize stover, and introduced interventions in processing, particularly mechanical chopping. In CSISA sites with more intensive dairy cattle production (Bihar and some sites in Odisha), ILRI improved the use of concentrate feeding within farmer's feeding practices. The use of mineral mixtures was also introduced where appropriate and feasible (Odisha, Bihar). ILRI's field-based work in the hubs was complemented by lab-based work on phenotyping to identify superior lines of maize and rice varieties; this work identified maize and rice cultivars with potentially superior straw quality for feed for dissemination.

ILRI made use of existing social structures such as milk societies, producer groups, and self-help groups in targeting farmer-collaborators, enabling the uptake of feed technologies and practices by capitalizing on 'strong' social ties between their members, while providing critical services that led to perceptible benefits from the interventions. Partnerships with milk societies supported through state level milk cooperatives provide a strong market incentive, but since the off-take of milk through formal channels is still relatively limited and in some areas absent, collaboration with other local organizations remains an important aspect in the scaling strategy. Local service providers could play an important role in meeting the demand for high quality feed and other services by making use of so-called 'weak' ties.

In Bihar, around 1,500 farmers across six districts adopted urea-treated maize stover as feed, and self-prepared balanced concentrate feed and mineral mixture as feed supplements to basal diets of their dairy cows. In Odisha, 1,200 farmers across three districts adopted chopped straw and fodder grass as basal diets of their dairy cows, supplemented with improved concentrated feed and mineral mixture. In Bangladesh, 150 farmers adopted maize stover as feed and 1,553 farmers practiced mechanical chopping of crop residues, of which two out of every three is female. In Nepal, 700 farmers adopted chopped straws as basal diet supplemented with self-prepared balanced concentrate feed and mineral mixture, showing an increase from 10% (pre-CSISA interventions) to 40% of farmers within and outside CSISA farmer group collaborators.

Through the various trainings and capacity-strengthening activities in CSISA II, the development of auxiliary service enterprises was also stimulated, revealing the entrepreneurial tendencies of our collaborators in the hubs. For example, 8 service providers in Bihar and 5 SPs in Odisha have been established for preparing balanced concentrate feed, while 12 SPs have been established in Bangladesh to provide straw chopping services in response to increased demand for chopped straw and fodder. In addition, two fodder markets were established in collaboration with local partners to serve increased demand for fodder, which have made fodder easily accessible and widely available while providing income-generating opportunities for fodder growers. With the introduction of fodder crops and forages as part of a basket of feeding options, farmers in CSISA sites were able to expand their feed resource base, helping them mitigate productivity constraints arising from seasonal variability and low quality of available feeds.

POLICY

During Phase II, CSISA's policy component developed a critical mass of research and communications work needed to take forward an actionable evidence-based agenda for improving public policies and investments in South Asia's cereal systems. Priority areas included private investment and public–private partnerships in pro-poor technology development and delivery; and interventions aimed at addressing the effects of new products and services on labor, gender, households, and migration.

Encouraging private investment and public–private partnerships in pro-poor technology development and delivery

Seed systems and markets: Effective, inclusive and competitive seed markets are critical to delivering modern science to smallholders in CSISA's target countries and ecologies. CSISA's policy component highlighted several areas where reforms are within reach.

In Bangladesh, CSISA identified the need for a phased withdrawal of the state-owned Bangladesh Agricultural Development Corporation —in the spirit of the 1993 National Seed Policy—from certified and truthfully labeled seed production, especially in the higher-value market for maize hybrids and horticulture seed. This withdrawal, accompanied by regulatory easing and business reforms, would encourage private firms and cooperatives to expand their commercial seed businesses.

India, on the other hand, already hosts a vibrant seed industry, implying that the public policy priorities should focus more on solving the regulatory uncertainty around seeds, traits, and innovation, particularly for genetically modified crops. The extent to which India's private sector invests in innovation and product markets for cereal crops will depend partly on reducing the uncertainty that characterizes the commercial viability of agricultural biotechnology and the availability of legal protections over intellectual property.

In Nepal, meanwhile, the situation is far more acute. Efforts to move the National Seed Vision into its implantation phase are being challenged by opponents of private and foreign direct investment in the seed market, potentially setting the stage for a protracted contestation without a sufficient evidence base against which to understand the consequences. CSISA is playing a role in framing the issues in a more constructive manner and building an actionable evidence base on which to find common ground.

Finally, across all three countries, CSISA is encouraging public investment in seed system data and analytics. The creation of an open-access information/analysis portal that provides spatially disaggregated, variety-specific data on seeds and traits could provide policy advisors, researchers and entrepreneurs with information critical to the development of a more dynamic, competitive, and responsive seed system.

Input subsidies and subsidy targeting. Subsidies on seed, machinery, equipment, power, and water are common interventions used across South Asia. They can be useful in promoting technology adoption and securing political support for a national development agenda. But these outcomes often come at a high price of forgone spending on other development priorities, rent-seeking behavior and corruption, and crowding out of private investment in the sector. CSISA has identified a number of cases where input subsidies are falling short of their potential in the promotion of sustainable agriculture in the project's target countries and ecologies. CSISA's work highlights the social and economic tradeoffs associated with poorly targeted subsidies on hybrid rice, laser land levelers, mechanical rice transplanters, zero tillage seeds, and other inputs, and suggests alternative strategies for improving the impact and lessening the damages caused by subsidies.

In many Indian states, for example, laser land levelers are often sold with an explicit subsidy on the purchase price that can reach up to 50%. CSISA's work on laser land levelers shows that under farmers' conditions in eastern Uttar Pradesh, the technology reduces groundwater extraction by 25% and saves farmers INR 400 in diesel fuel costs each year. However, a first-hour discount on custom-hired leveling services is a more cost-effective targeting strategy for reducing groundwater extraction than the current blanket subsidy on purchase price.

Technology development, delivery, and partnership: As part of its partnership with national research and extension systems in South Asia, CSISA has played a central role in identifying organizational needs and worked to strengthen innovative capabilities. Beyond simply reviewing current agricultural research investment portfolios and extension strategies, CSISA helped national systems gear their attention toward the central issue of sustainable intensification in its risk-prone cereal systems and the role of new partnerships with the private sector.

Changing labor, gender, assets, and migration dynamics related to pro-poor technology development and delivery: In India, Bangladesh, and Nepal, CSISA helped identify the potential role and impact of more effective gender-based approaches to extension. CSISA's work demonstrates that female social networks can help farm households gather more information about a technology than they would receive through male networks alone. This may be particularly important with technologies that directly affect female labor supply, for instance, mechanical rice transplanters, self-propelled reapers, or maize shellers.

In Bangladesh and India, CSISA has explored the scope for alternatives to highly subsidized crop insurance schemes currently in favor with governments. Findings from recent studies suggest that in some contexts, farmers are willing to pay for low-cost weather index insurance products at or above actuarially fair values when offered in conjunction with or separate from a complementary abiotic stress-tolerant rice cultivar. This suggests scope for improving the design and implementation of agricultural insurance schemes for smallholders.

In India, CSISA's work suggests that continued reverberations between labor, technology, and NREGA in the rural economy can result in a win-win situation for farm owners and laborers to the extent that the technologies adopted increase farm productivity and that newly created NREGA infrastructure increases market access.

Communications and Outreach

During Phase II, IFPRI and the Institute of Economic Growth convened a high-level international policy conference titled "Innovation in Indian Agriculture" in New Delhi on December 4–5, 2014. IFPRI and CSISA then convened a second private sector roundtable on "Deepening Private Sector Engagement in the Vulnerable and Underserved Markets of Eastern India" in New Delhi on December 8, 2014. In 2015, the Modernizing Extension and Advisory Services project, CSISA, and IFPRI organized a learning event on "Strengthening Agricultural Research, Extension, and Input Markets in South Asia: Evidence from Regional and Global Practice,," in Washington, DC, June 8–9, 2015. Finally, IFPRI, along with CIMMYT, IRRI, and other CSISA partners, contributed to the National Seed Summit convened by the Nepal Ministry of Agricultural Development, Kathmandu, September 14–15, 2015.

Cereal Systems Initiative for South Asia (CSISA)

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